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ABSTRACT

This document consists of materials for an eight-unit course on the following topics: (1) grinder safety and types of grinders; (2) surface grinder accessories and equipment maintenance; (3) surface grinder preparation and set-up; (4) surface grinding flat and angular surfaces; (5) cylindrical grinding; (6) tool and cutter safety; (7) tool and cutter grinding wheels; and (8) machine set-up and cutter sharpening. The instructor's guide begins with a list of competencies covered in the module, descriptions of the materials included, an explanation of how to use the materials, and information on how the curriculum guide is packaged. Next is a table that associates individual instructional materials in the units with the competencies they teach. The instructional units follow, each of which may include unit objectives, lesson objectives, lesson plans, references, notes to the teacher, information sheets or outlines, transparency masters, handouts, assignment sheets, job sheets, unit tests, and answers to tests. (CML)

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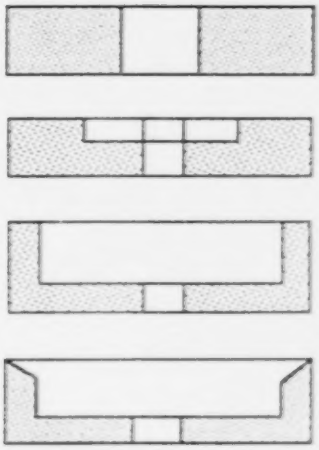
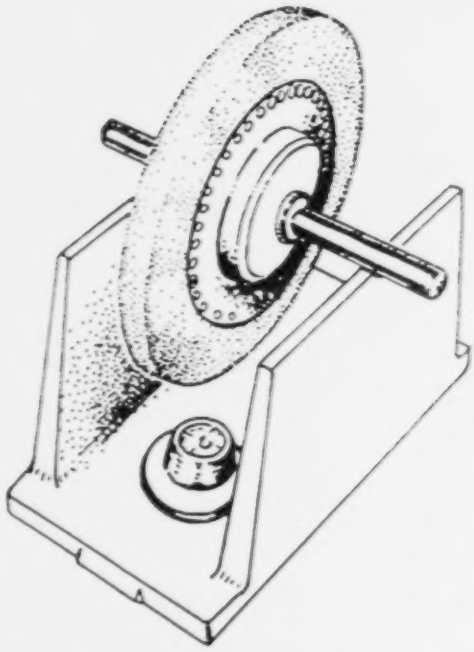
MACHINE SHOP CURRICULUM

INSTRUCTOR'S GUIDE

MODULE 7: Grinders





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MACHINE SHOP

Module 7: Grinders

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FOREWORD

Once again, we are indebted to the teachers and administrators who provide their time, efforts and professionalism to develop curriculum for trade, technical and industrial education programs. This Machine Shop guide is an outstanding example of what can be accomplished when the right people with the right attitude get together. Committee members worked hard over several years' time in advisory, writing, technical consultation and field-test capacities.

This guide is designed to be totally integrated with the Vocational Instructional Management System. It is hoped that all guides produced under our supervision will help classroom teachers manage instruction. A curriculum guide is more than a resource--it is an integral part of the management system. Rather than impeding instruction, it should guide and facilitate instruction.

This guide's format has been set up for competency-based teaching and testing. Unit tests evaluate specific competencies and can be used with the Vocational Administrative Management System (VAMS). Information sheets, transparency masters, job sheets, assignment sheets and test items are keyed to specific competencies. A cross-reference table has been included to quickly identify parts of the curriculum that relate to specific competencies. The material has also been packaged for students.

Although this guide may be a new format for some teachers, we are confident that, when used as designed, time spent by teachers and students will become more productive. Any future machine shop curriculum modifications will begin with this guide. The machine shop field is undergoing considerable change. We will annually evaluate the need to update this guide on a module-by-module basis. Your suggestions regarding areas for improvement are both encouraged and appreciated.

Judith Moore, supervisor
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Charles "Chuck" Waibel, director
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ACKNOWLEDGMENTS

This Machine Shop guide represents a continuing commitment to Missouri's Vocational Instructional Management System (VIMS). The guide has been keyed to the machine shop competency profile developed by industry and education professionals in the state.

Appreciation is given to the writers (Charlie Walden, Jack Nobles, Dwight Crosswhite, Donna Curtis, Don Marquardt, Bill Daniel, Mel Gage and Jr. Cagle) for their technical expertise. Catherine Smith of Dodge Art Works, Columbia, created a large portion of the guide's artwork.

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TABLE OF CONTENTS

Unit I: Safety and types 1

Unit II: Surface grinder accessories and equipment maintenance 29

Unit III: Surface grinder preparation and set-up 55

Unit IV: Surface grinding flat and angular surfaces 103

Unit V: Cylindrical grinding 149

Unit VI: Tool and cutter safety 203

Unit VII: Tool and cutter grinding wheels 217

Unit VIII: Machine set-up and cutter sharpening 231

COMPETENCIES ADDRESSED IN THIS MODULE

I. Operating Lathes

34. Use mandrel

K. Operating Grinders

1. Employ grinder safety guidelines consistently
2. Clean and lubricate grinders
3. Select and apply cutting fluids
4. Inspect grinding wheel
5. Balance grinding wheel
6. Select and mount grinding wheel
7. Dress and true machine tool grinding wheel
8. Grind workpiece on magnetic chuck using power feed
9. Grind workpiece square on surface grinder
10. Indicate workpiece to be ground
11. Grind angular surfaces
12. Grind workpiece between centers using cylindrical grinding

L. Tool and Cutter Grinding

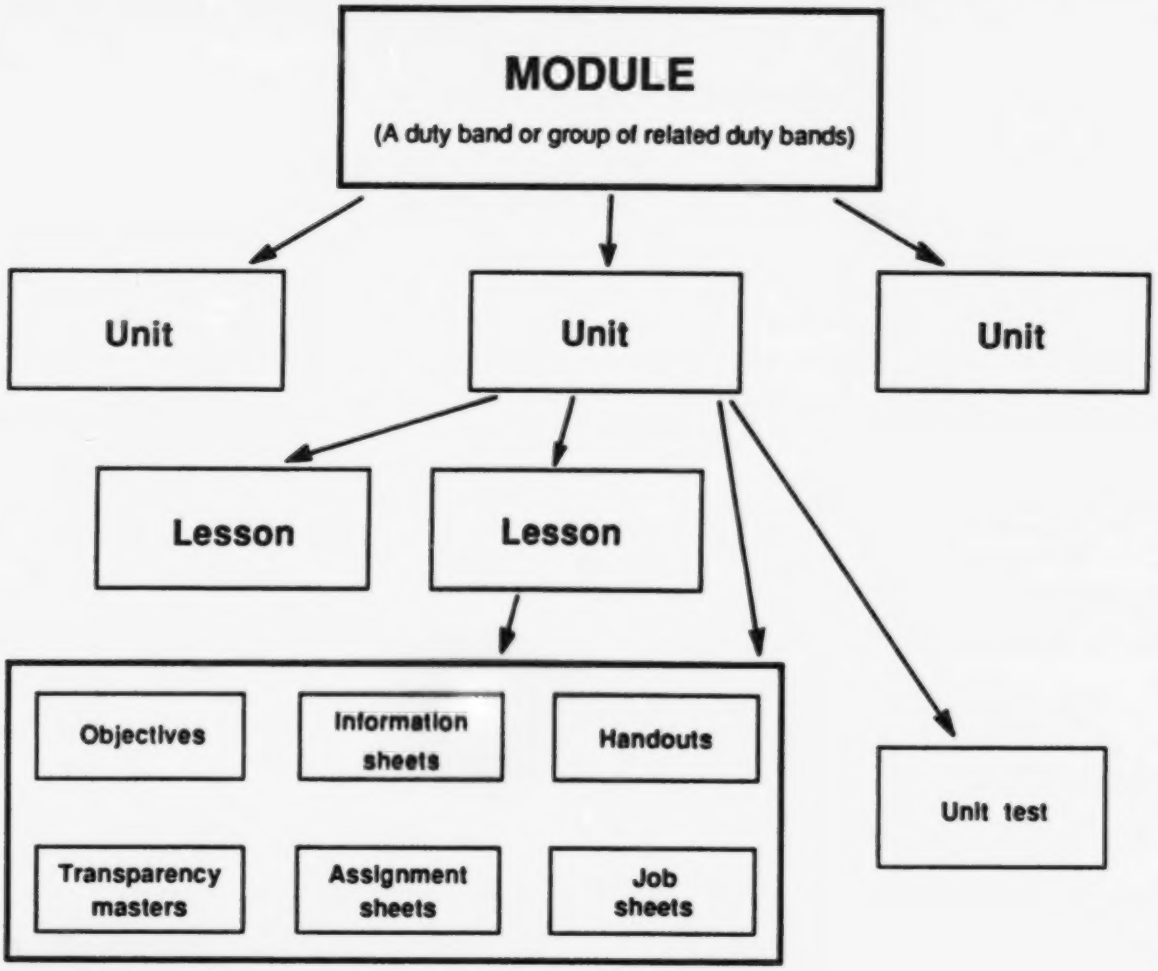
1. Employ safety guidelines
2. Perform care and maintenance
3. Inspect grinding wheels
4. Select and mount grinding wheel
5. Dress and true grinding wheel
6. Set up machine
7. Sharpen cutters on tool and cutter grinders

HOW TO USE THIS PUBLICATION

GUIDE COMPONENTS

Units of instruction

This Machine Shop guide contains eight modules of instruction. Within each module are instructional units including some or all of the following components: performance objectives, information sheets, transparency masters, handouts, assignment sheets, job sheets and a unit test. Special instructions on audiovisuals, supplies, etc. are included in the Notes to the Instructor section near the beginning of each unit.



Competency profile

On the Missouri competency profile, tasks are divided into general subject areas, or duty bands, which are identified by a capital letter. Under each duty band are related tasks (competencies), which are identified by an Arabic numeral. To evaluate the student on performance of the competencies, a 3-2-1-N grading system is used, where:

- **3 = Mastery** - can work independently with no supervision
- **2 = Requires supervision** - can perform job completely with limited supervision
- **1 = Not mastered** - requires instruction and close supervision
- **N = No exposure** - no experience or knowledge in this area

Cross-reference table (color-coded white)

Once the numbering system is understood, this table quickly reveals how the instructional components of the module relate to Missouri competencies. On the competency profile, tasks are divided into general subject areas, or duty bands, which are identified by a capital letter. Under each duty band are related tasks (competencies), which are identified by an Arabic numeral.

On the cross-reference table, unit numbers are represented by Roman numerals (I, II, III, etc.). Lessons within a unit are shown with Arabic numerals. Therefore, the first objective in Lesson 1 is numbered 1.1, the second is 1.2, and so on. Other components of the module (transparencies, handouts, assignment sheets and job sheets) also use this numbering system. By looking at the cross-reference table, the instructor can quickly determine what test questions or job sheets a student needs to receive an evaluation on a particular competency.

Objectives (color-coded white)

Each unit is based on performance objectives which state the measurable unit and specific behavioral or performance objectives that students are expected to achieve. Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the objectives' intent. Teachers should feel free to add/adapt objectives which will fit the material to student and community needs. Supporting material will, of course, need to be added for any new objectives.

Table of contents, references, notes to the instructor (color-coded pink)

These pages have been coded pink for instructor use only. The reference section lists materials used as sources in developing the material. Special instructions on audiovisuals, supplies, etc. are included in the Notes to the Instructor section.

Information sheets (green)

Presented in outline form for clarity, these pages provide content essential for meeting the cognitive (knowledge) objectives in the unit. Students should study the information sheets before class discussion or completion of assignment sheets. **CAUTION** statements indicate possible equipment damage or bodily injury. Handouts and transparency masters have been keyed in the information sheets for instructional use.

Transparency masters (white)

Transparencies provide information by visually reinforcing or clarifying ideas presented in the information sheets. They are effective when identification is necessary and direct the class's attention to the topic of discussion. Transparencies should be left on the screen only when topics shown are under discussion, however.

Handouts (white)

Whenever more detailed information than can be presented in a transparency is needed, a handout is used. Handouts give the students additional information that can be kept with their class notes or student references.

Assignment sheets (tan)

Assignment sheets furnish paper-and-pencil practice to develop the knowledge necessary as a prerequisite to skill development. They can be given to students for class completion or used as homework assignments. Answer sheets (color-coded pink) can be used by the student or instructor to check progress.

Job sheets (blue)

These evaluation instruments are provided for two purposes: to outline steps of procedure and to check student performance mastery. Job sheets begin with a list of tools and materials needed for the activity. Job sheets furnish potential employers with a picture of skills being taught and performance which might be reasonably expected from a vocational student. The spaces to the right of the page on a job sheet

assist the instructor in evaluating a student on a particular activity. This 3-2-1-N grading system is the same as the one used on the competency profile.

Unit test (yellow)

Competency-based tests are designed to help eliminate subjective testing and to improve student evaluation and accountability. Specific competencies and test questions are linked on the answer key. These unit tests have been written to be used with computerized VAMS (Vocational Administrative Management System), utilizing Scantron sheets for computer-recording of test answers.

The unit test may be eliminated if the competency was thoroughly evaluated by job sheets. However, an emphasis should be placed on cognitive as well as performance skills. If the objective or competency will be evaluated by a job sheet, it is often necessary to determine by a written test whether the student understands enough of the material to perform the job sheet.

SUGGESTED ACTIVITIES

The following list of suggested activities may be helpful, especially to the beginning instructor.

1. Provide students with objective sheet and information sheets.
2. Discuss unit and specific objectives.
3. Discuss information sheets, assignment sheets and/or job sheets, lesson-by-lesson.
4. Have students do assignment sheet(s) to satisfactory levels.
5. Give students unit test.
6. After successful completion of the test, have students do job sheet(s).

Students should perform the following activities.

1. Read objective sheet.
2. Study information sheets.
3. Do assignment sheet(s).
4. Take unit test.
5. Do job sheets.

PACKAGING

This Machine Shop guide has been packaged with the entire class in mind. For the teacher, a complete instructor's guide contains all eight modules. In the student reference, selected portions have been reproduced for student use (objectives page, information sheets, handouts). Student work sheets (assignment sheets, job sheets, unit tests) have been packaged together for student distribution as the instructor deems necessary.

In the student reference, page numbers do not run consecutively because some pages have been removed that appear only in the instructor's guide.

MODULE 7: GRINDERS

CROSS-REFERENCE TABLE OF INSTRUCTIONAL MATERIALS

Competency	Instructional Objective	Transparency Master	Handout	Assignment Sheet	Job Sheet	Test Item	Notes
I34	III 1.6				III 1.3		Cognitive covered in Lathes Units VI and VIII
K1	I 1.1-1.3					I 36-45	
K2	II 1.1,1.3,1.5				II 1.1	II 1,2,8,15-17,19, 32-43	
K3	II 1.1,1.4,1.6				II 1.2	II 4,5,10,13	
K4	III 1.1,1.4				III 1.1	III 1-15	
K5	III 1.6	III 1.1			III 1.3	II 6	
K6	III 1.2,1.3,1.5	III 1.2	III 1.1	III 1.1	III 1.2	III 16-36	
K7	III 2.1-2.4	III 2.1			III 2.1	III 38-48	
K8	IV 1.1-1.4				IV 1.1	IV 1-15	
K9	I 2.2 IV 1.5	I 2.1		I 2.1	IV 1.2	I 1,2,4-5,7-23, III 37, IV 17,18,24	
K10	IV 1.6				IV 1.2	IV 19,20	
K11	IV 1.3,1.7	IV 1.1,1.2		IV 1.1,1.2	IV 1.3	IV 16,22,23	
K12	I 2.3 V 1.1-1.7,2.1-2.4	V 1.1-1.4		V 1.1,1.2, 2.1, 2.2	V 2.1-2.3	I 3,6,24-35 V 1-49	
L1	VI 1.3,1.4					VI 1-7	
L2							I Note to instructor
L3	VII 1.2					VII 1-4,7,8	

Competency	Instructional Objective	Transparency Master	Handout	Assignment Sheet	Job Sheet	Test Item	Notes
L4	VII 1.1,1.3, VIII 1.5		VIII 1.1,1.2		VIII 1.2	VII 9-16	
L5	III 1.5, VII 1.4				VIII 1.1,1.2	VII 5,6, VIII 3,4	
L6	VII 1.2,1.4,1.5				VIII 1.1	VIII 5,8,9,12	
L7	VIII 1.1,1.3,1.5				VIII 1.1,1.2	VIII 1,2,6,7,10,11	

MODULE: GRINDERS

UNIT I: SAFETY AND TYPES

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to identify types of grinding machines and name the basic parts of surface and cylindrical grinders. The student should also be able to identify hazardous conditions and safety rules for operating grinding machines. This knowledge will be evidenced by achieving specified scores on the unit test.

SPECIFIC OBJECTIVES

1.1 Identify grinder safety rules.

1.2 Select appropriate eye and hand safety guidelines.

1.3 Employ grinder safety guidelines consistently. (competency K1)

2.1 Identify the four major types of grinding machines and their cutting actions.

2.2 Identify the major parts of the surface grinder.

2.3 Identify the major parts of the cylindrical grinder.

MODULE: GRINDERS

UNIT I: SAFETY AND TYPES

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: GRINDER SAFETY

   a. Information outline

2. Lesson 2: TYPES OF GRINDING MACHINES

   a. Information outline

   b. Transparency masters

      TM 2.1: Surface grinder nomenclature
      TM 2.2: Universal cylindrical grinder parts and nomenclature

   c. Assignment sheet

      AS 2.1: Parts and functions of surface grinder

   d. Answers to assignment sheet

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Kibbe, Richard R., et. al. Machine Tool Practices. New York: John Wiley and Sons, 1979.

2. Krar, S. F. and J. W. Oswald. Grinding Technology. Albany, NY: Delmar Publishers, Inc., 1984.

3. Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987.

B. Curriculum guides

1. Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983.

2. Machinist. Frankfort, KY: Vocational-Technical Education Consortium of States, 1982.

3. Yettaw, Jerome. Vocational Machine Shop. University of Missouri-Columbia: Instructional Materials Laboratory, 1977.

C. Manual

1. Operation and Maintenance Manual of the 618 and 818 Micromaster Series II Surface Grinding Machines. North Kingstown, RI: Brown and Sharpe Co., 1980.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Show examples of grinding machines available in the shop.

2. Demonstrate proper use of safety equipment. Give students examples of types of injuries that can occur when grinding.

B. Suggested supplemental materials

1. Operation and Maintenance Manual of the 618 and 818 Micromaster Series II Surface Grinding Machines. North Kingstown, RI: Brown and Sharpe Co., 1980.

2. Oberg, Erik; Franklin D. Jones; Holbrook L. Horton. Machinery's Handbook. 23rd ed. New York: Industrial Press, Inc., 1988.

MODULE: GRINDERS

UNIT I: SAFETY AND TYPES

LESSON 1: GRINDER SAFETY

I. Grinder safety rules

A. Store grinding wheels in a storage rack. Use protective, corrugated shims between wheels. Place each wheel in its proper compartment.

B. Handle wheels carefully. Avoid hitting a wheel, particularly on its edges.

C. Check the outside diameter of the wheel (if worn) and the recommended maximum speed on the wheel blotter. Adjust the spindle to keep within the manufacturer's range.

D. Use a guard that covers at least half the diameter of the wheel. Adjust the spark guard and work rest on a high-speed grinder.

E. Stand to side of the grinding wheel, particularly during start-up.

F. Bring the wheel speed up to operating speed. Run at this speed for about a minute before taking a cut.

G. Use only the recommended face(s) of a grinding wheel as designed and specified for each process.

H. Shut off coolant at the operation's end before stopping the spindle to prevent the coolant from collecting at the bottom of the wheel.

NOTE: Coolant collection produces an out-of-balance condition.

I. Only one operator at a time should control the grinder.

II. Eye and hand safety

A. Proper eye protection should be worn in a machine shop under all conditions.

B. In the presence of sparks, chips and abrasive dust, a proper face shield and/or goggles must be worn as well.

C. For hygienic reasons, it is best to have your own personal eye protective equipment.

D. Never use hands or any part of the body to brake the machine to a stop.

E. Always keep hands and body away from all moving parts.

NOTE: Before attempting to relocate or load the machine, position the table forward toward operator with grinding wheel behind the workpiece.

III. General safety rules

A. Do not operate any machine before receiving instructions on the correct and safe procedures from the instructor/supervisor. It is not wise to ask another student for proper procedures.

B. All machines should have effective guards that are in place when machines are operating.

C. Do not wear loose clothing; roll up sleeves; remove ties; rings, watches, etc; tie long hair out of the way.

D. Keep tools and other materials in their proper places. Keep the floor clear of chips and objects that could cause a worker to trip. Immediately remove oil or any other spills from the floor.

E. When lifting heavy objects, follow safe lifting procedures. Get help if necessary.

F. No matter how slight, cuts, scratches, bruises, burns and punctures should be reported to the instructor/supervisor without delay.

NOTE: First aid should be administered immediately to prevent the possibility of infection.

G. Proper and adequate ventilation (exhaust fans) is mandatory, especially when grinding dust or when coolant mist is heavy.

H. Proper protective clothing (jackets, pants, shoe guards, leather boots, etc.) is mandatory, especially when operation is hazardous.

I. Never use compressed air to clean or dry skin or clothing because of the air's intensity.

J. Do not allow any unprotected person in the work area of grinding or machinery operations.

K. Never make repairs or attempt to service equipment unless all electric, hydraulic and pneumatic power has been properly disconnected.

MODULE: GRINDERS

UNIT I: SAFETY AND TYPES

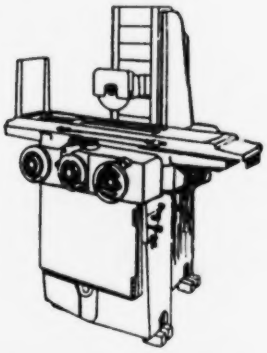
LESSON 2: TYPES OF GRINDING MACHINES

I. Types of grinding machines **(TM 2.1, 2.2)**

A. Type I surface grinder (horizontal-spindle, reciprocating-table)

1. Surface grinders are most commonly used to produce flat, shoulder, angular or formed pieces.

2. The workpiece is moved longitudinally under the abrasive wheel on the reciprocating table.



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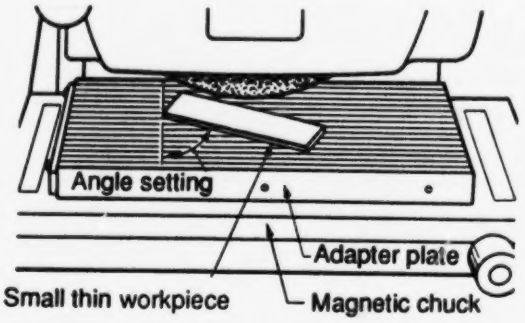


Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987, pg. 528.

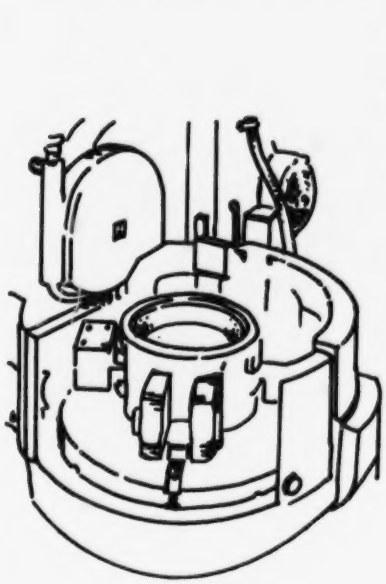
B. Type II surface grinder (horizontal-spindle, rotary-table)

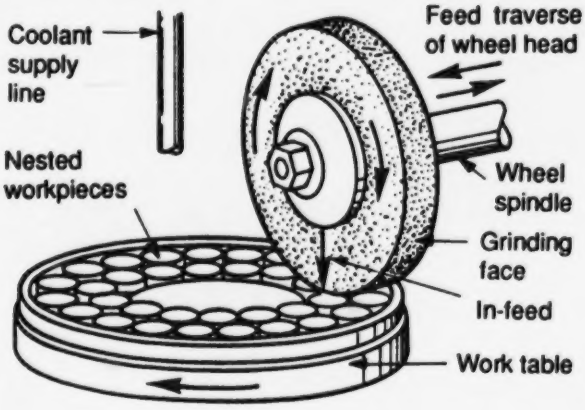
1. Surface grinders are designed to produce a circular, scratch-pattern finish.

a. Finish desirable for metal-to-metal seals of mating parts

b. Very flat surfaces obtained

2. Nested parts rotate in contact with one another. The traverse movement of the wheel head feeds the grinding wheel across the workpiece.

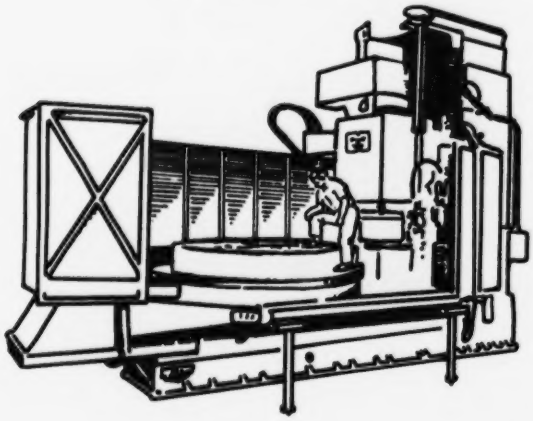


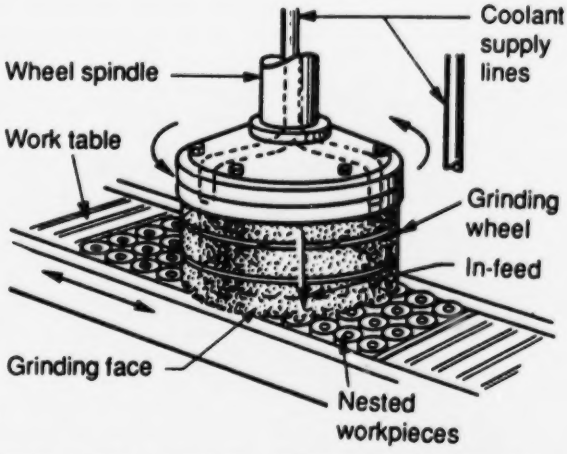


Credit: Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987, pg. 450.

C. Type III surface grinder (vertical-spindle, rotary-table)

1. This grinder is designed to grind on the face of the wheel.
2. Its wheel head is capable of taking comparatively heavy cuts.
3. Wheel can be tilted a few degrees from the vertical position.
4. Tilting permits faster cutting and metal removal as the rim of the grinding wheel contacts the workpiece.

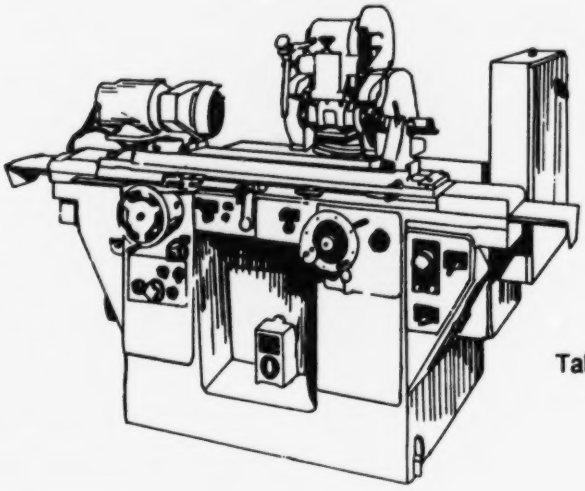


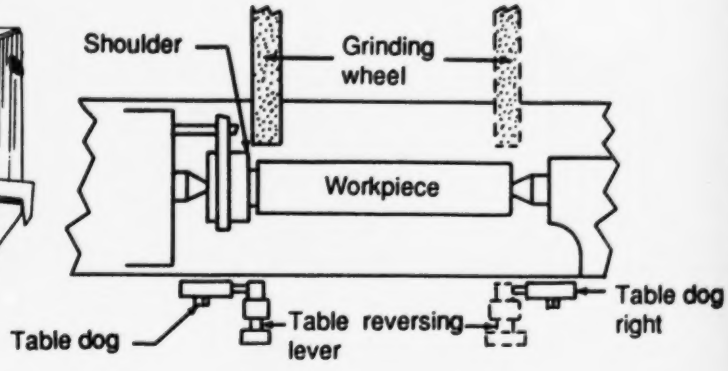


Credit: Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987, pg. 450.

D. Universal cylindrical grinding machine

1. Designed to produce straight or tapered cylindrical surfaces
2. Surfaces concentric or eccentric in relation to work axis
3. Cylindrical grinding accuracy
   a. Diameters within 25 millionths
   b. Roundness within 50 millionths
4. On universal types, the table is designed to swivel, whereas the table is stationary on plain types of cylindrical grinders.



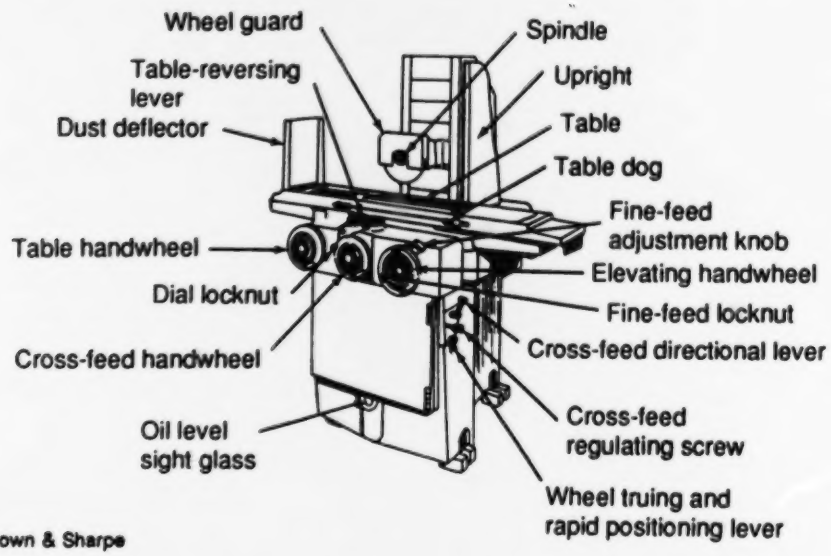


Credits: Brown & Sharpe

Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 291. Used by permission.

II. Major parts of a surface grinder

NOTE: The surface grinder illustrated here is an example of what may be found in the shop. Follow manufacturer specifications on individual machines used.



Credit: Brown & Sharpe

A. Spindle--aligns grinding wheel mounting hub and secures hub so that it runs true

B. Upright--houses motor, spindle and elevating mechanism; cross-feed regulating screw moves upright in and out on ways

C. Table--provides a flat surface to which workpiece or work-holding devices are mounted

D. Table dogs--regulate length of table travel by tripping table-reversing lever

E. Fine-feed adjustment knob--raises and lowers elevating mechanism of spindle for precision measurement. Graduations differ according to the machine's manufacturer.

F. Elevating handwheel--provides rapid up-and-down movement of spindle for coarse feed adjustment

G. Fine-feed locknut--when tightened, engages fine-feed adjustment knob; when loose, allows rapid movement by handwheels

H. Cross-feed directional lever--engages power-feed mechanism and allows upright to move in or out by power

I. Cross-feed regulating screw--regulates amount of step-over for each cut the wheel moves

J. Wheel truing and rapid positioning lever--moves upright in and out; overrides the feed setting; moves at a set, rapid rate

K. Oil level sight glass--allows visual inspection of oil level

L. Cross-feed handwheel--moves upright toward and away from table

M. Dial locknut--allows outer graduated ring of cross-feed or elevating wheel to be moved or set without moving feed mechanism

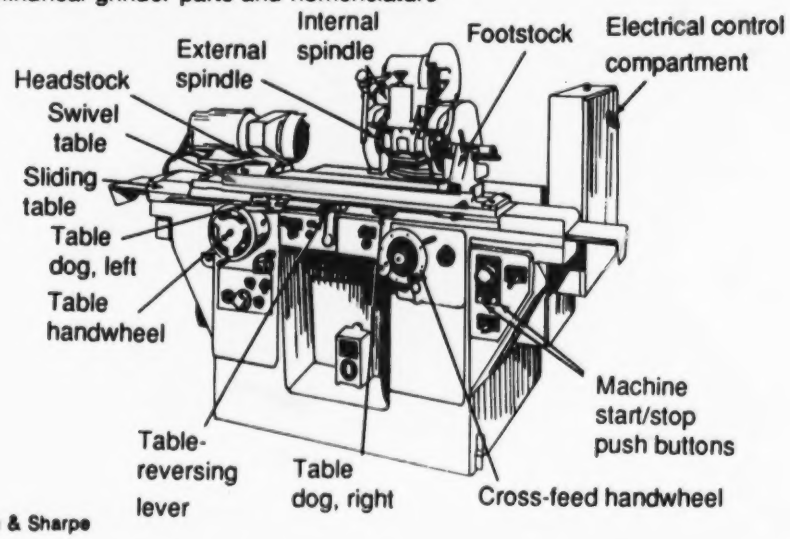
N. Table handwheel--moves table right or left

O. Dust deflector--shields user from dust and chipped particles from wheel or workpiece

P. Table-reversing lever--changes direction of table when moving right or left by power feed

Q. Wheel guard--helps control grinding dust and serves as protection if grinding wheel explodes

III. Universal cylindrical grinder parts and nomenclature



Credit: Brown & Sharpe

A. Headstock--supports workpiece and revolves workpiece at set surface feet per minute

B. External spindle--holds wheel and wheel hub for external grinding

C. Internal spindle--holds internal quill and wheels for grinding

D. Footstock--holds workpiece when set up between centers

E. Electrical control compartment--houses main power controls for all electrical components

F. Machine start/stop push buttons--start external spindle and provide power to other controls

G. Cross-feed handwheel--moves spindle upright in (toward table) or out (away from table) by manual feed

H. Table reversing lever--reverses direction of sliding table when table is under power feed

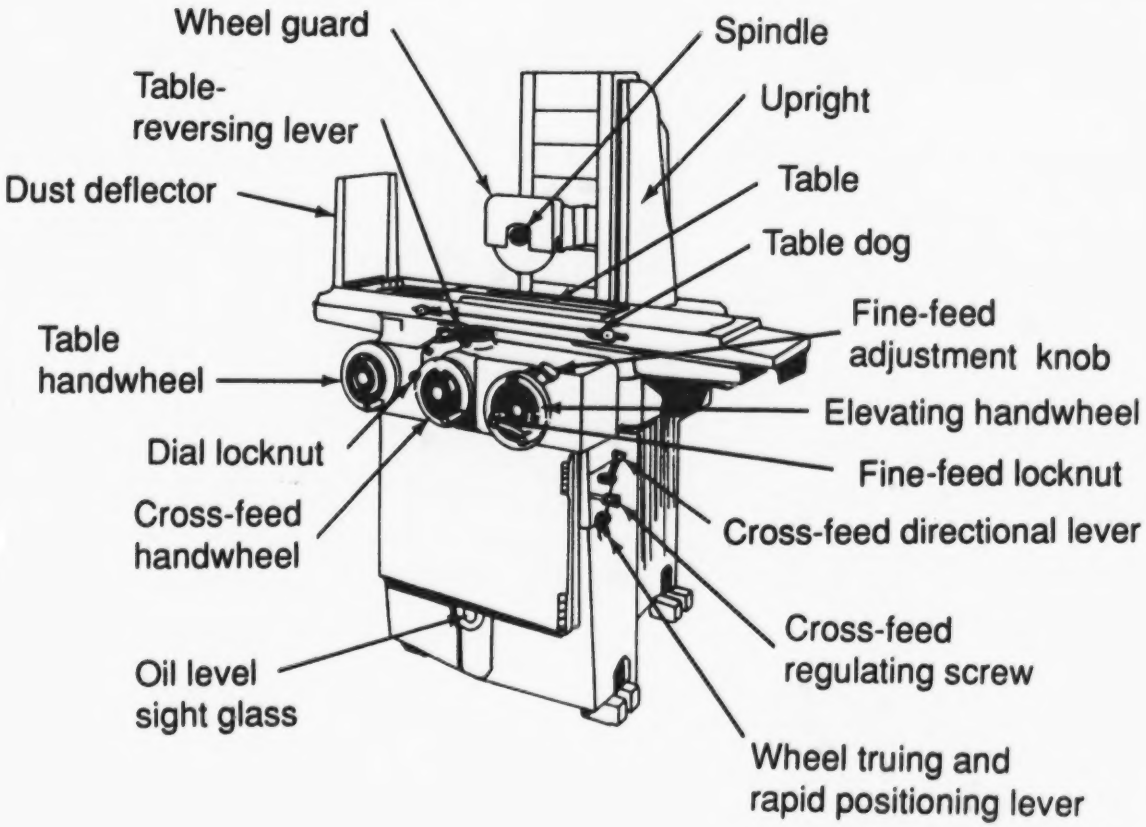
I. Table handwheel--moves sliding table right or left by manual feed

J. Table dogs--regulate direction of table movement by striking table-reversing lever as table moves by power feed

K. Sliding table--table's main part; moves right and left by power or manual feed; carries swivel table

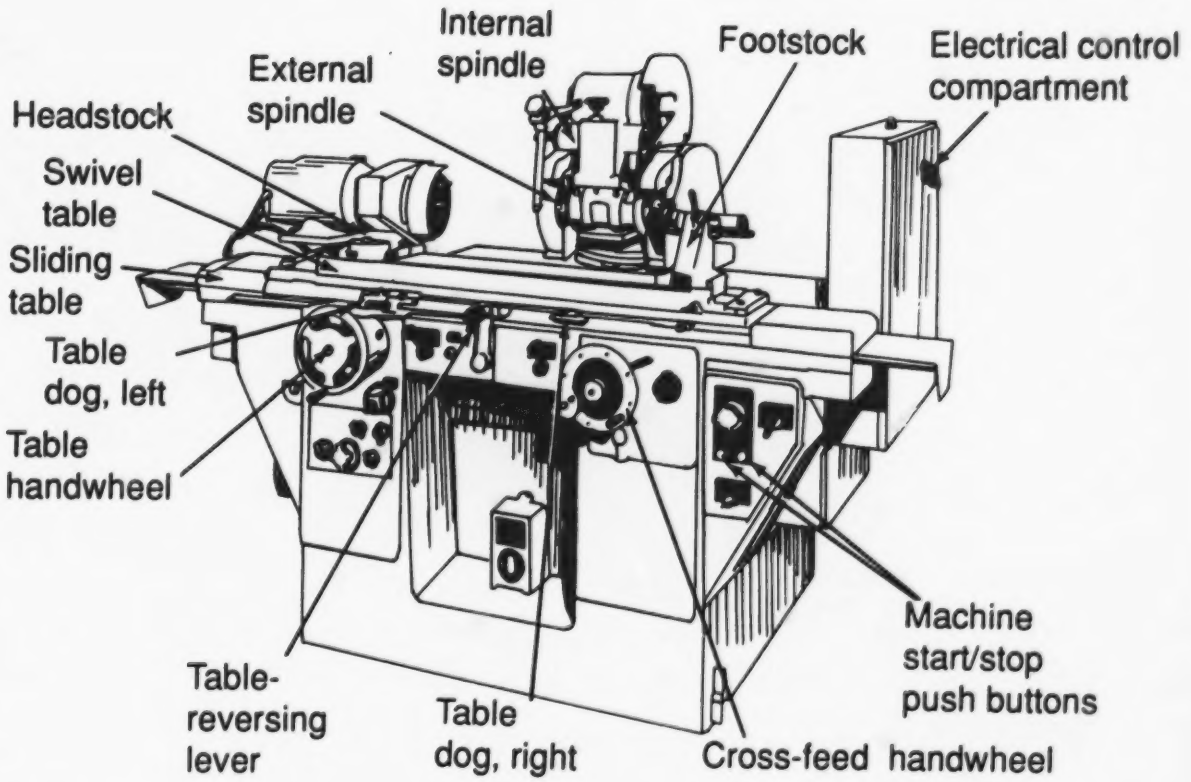
L. Swivel table--top part of sliding table; has T-slot for mounting work-holding devices or wheel dresser; adjustable to allow grinding of tapers

SURFACE GRINDER NOMENCLATURE



Credit: Operation and Maintenance Manual of the 618 and 818 Micromaster Series II Surface Grinding Machines. North Kingstown, RI: Brown and Sharpe Co., 1980.

UNIVERSAL CYLINDRICAL GRINDER PARTS AND NOMENCLATURE



Credits: Dunn, James. Machine Shop Grinding Machines. Oklahoma State Board of Vocational and Technical Education, 1983. Used by permission.

Brown and Sharpe Manufacturing Company

PARTS AND FUNCTIONS OF SURFACE GRINDER

Match surface grinder parts to functions.

____ 1.	Allows visual inspection of oil level	a. Upright
____ 2.	Houses motor, spindle and elevating mechanism; moves in and out by means of cross-feed regulating screw	b. Cross-feed handwheel
____ 3.	Allows outer graduated ring of cross-feed or elevating wheel to be moved or set without moving feed mechanism	c. Table-reversing lever
____ 4.	Regulates length of table travel by tripping table-reversing lever	d. Dial locknut
____ 5.	Moves upright in and out; overrides the feed setting and moves at a set, rapid rate	e. Spindle
____ 6.	Provides rapid up-and-down movement of spindle for coarse feed adjustment	ab. Elevating handwheel
____ 7.	Changes direction of table when moving right or left by power feed	ac. Wheel guard
____ 8.	Engages power-feed mechanism and allows upright to move in or out by power	ad. Cross-feed regulating screw
____ 9.	Regulates amount of step-over for each cut the wheel moves	ae. Table handwheel
____ 10.	Raises and lowers elevating mechanism of spindle for precision measurement. Gradations differ according to machine manufacturer.	bc. Fine-feed adjustment knob
____ 11.	Aligns grinding wheel mounting hub and secures hub so that it runs true	bd. Oil level sight glass
____ 12.	Moves upright toward and away from table	be. Table dog
____ 13.	Moves table right or left	cd. Wheel truing and rapid positioning lever
____ 14.	When tightened, engages fine-feed adjustment knob; when loose, allows rapid movement by handwheels	ce. Fine-feed locknut
____ 15.	Helps control grinding dust and serves as protective guard in case grinding wheel explodes	de. Cross-feed directional lever

ANSWERS TO ASSIGNMENT SHEET 2.1

1. bd
2. a
3. d
4. be
5. cd
6. ab
7. c
8. de
9. ad
10. bc
11. e
12. b
13. ae
14. ce
15. de

MODULE: GRINDERS

UNIT I: SAFETY AND TYPES

UNIT TEST

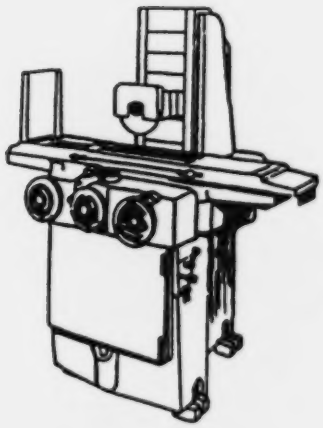
Identify the grinding machine types and cutting actions by placing the appropriate letter in the blank.

a. Horizontal surface grinder (Type I)

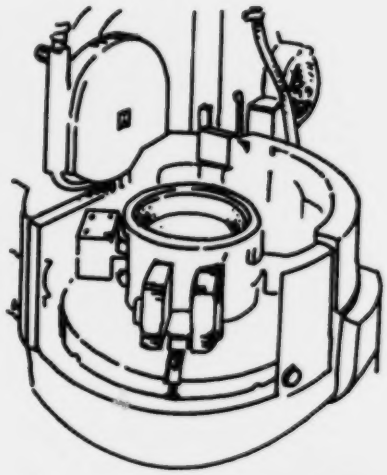
b. Horizontal-spindle, rotary-table surface grinder (Type II)

c. Vertical-spindle, rotary-table surface grinder (Type III)

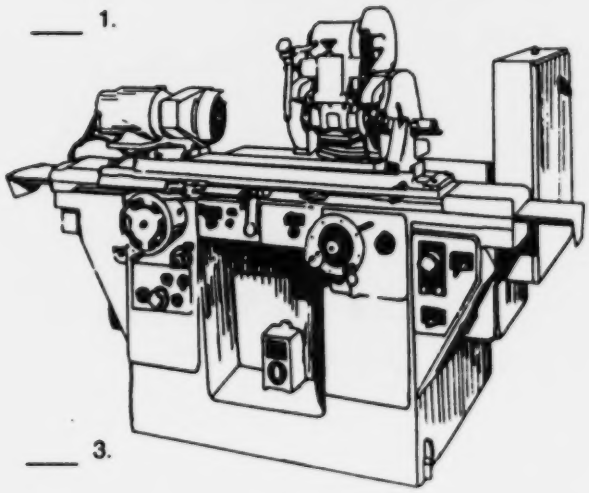
d. Universal cylindrical grinding machine



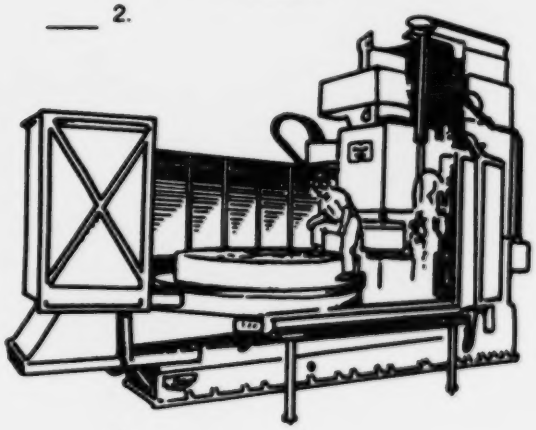
___ 1.



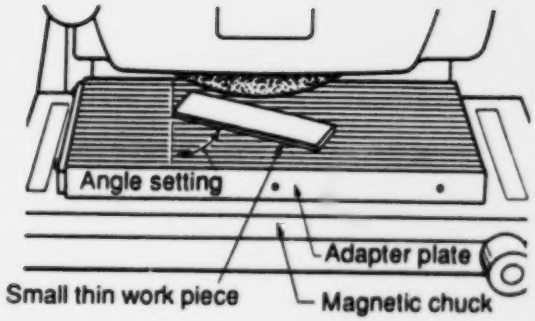
___ 2.



___ 3.

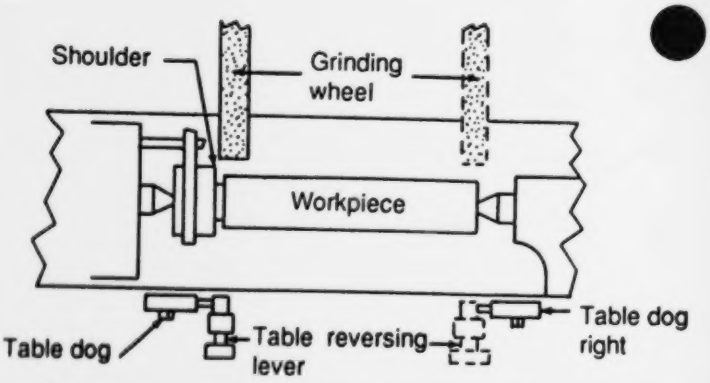


___ 4.



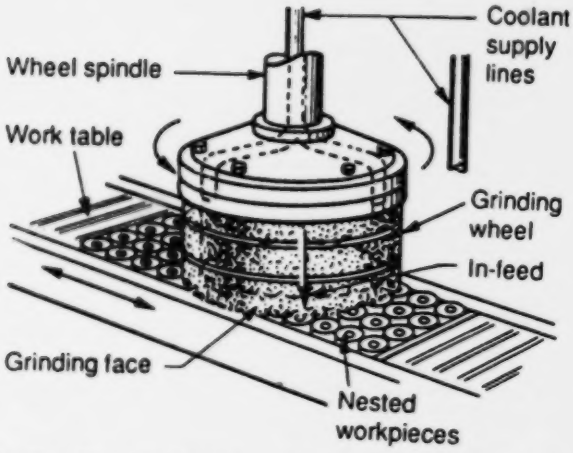
Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987, pg. 528.

___ 5.



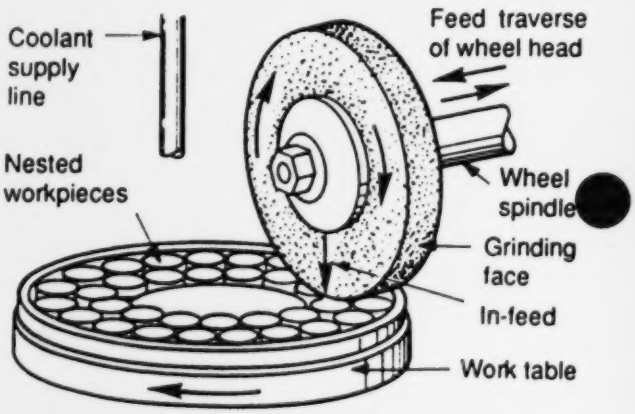
Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 291. Used by permission.

___ 6.



Credit: Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987, pg. 450.

___ 7.



Credit: Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987, pg. 450.

___ 8.

Match the letter on the surface grinder below with the appropriate term for the part in the list that follows.

___ 9. Wheel guard

___ 10. Dial locknut

___ 11. Cross-feed regulating screw

___ 12. Cross-feed directional lever

___ 13. Elevating handwheel

___ 14. Fine-feed adjustment knob

___ 15. Table

___ 16. Table-reversing lever

___ 17. Table handwheel

___ 18. Cross-feed handwheel

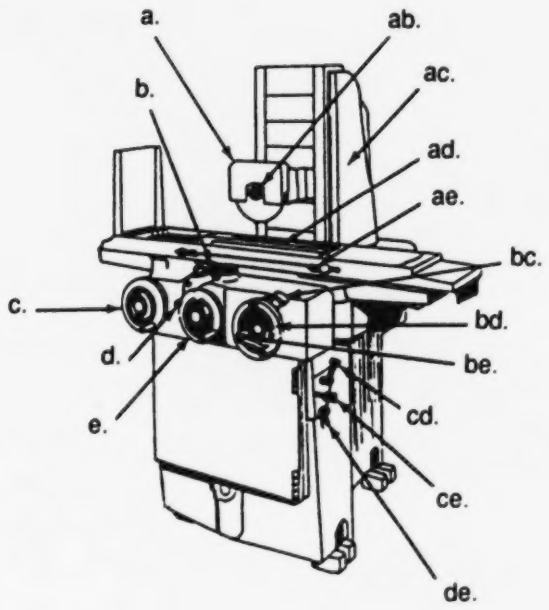
___ 19. Wheel truing and rapid positioning lever

___ 20. Upright

___ 21. Fine-feed locknut

___ 22. Table dog

___ 23. Spindle



Match the letter on the cylindrical grinder below with the appropriate term for the part in the list that follows.

___ 24. Headstock

___ 25. Internal spindle

___ 26. Electrical control compartment

___ 27. Footstock

___ 28. External spindle

___ 29. Machine start/stop push buttons

___ 30. Cross-feed handwheel

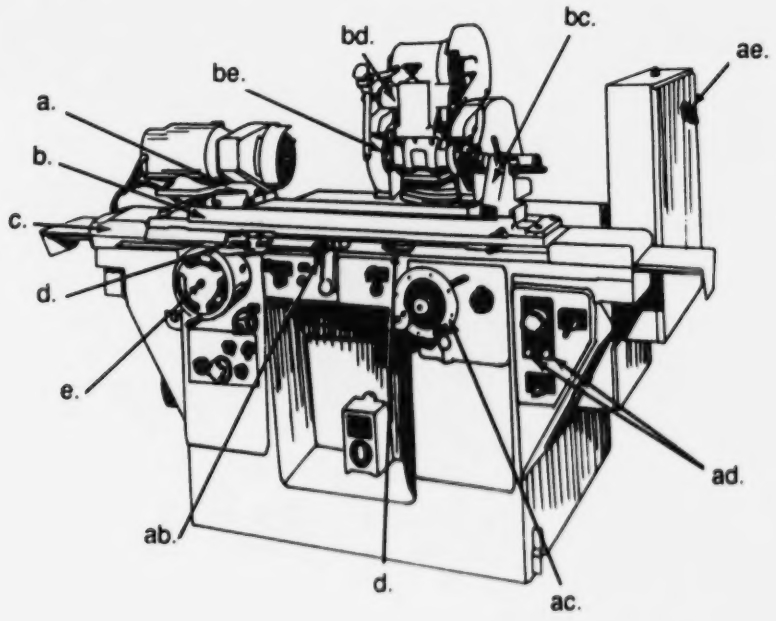
___ 31. Table handwheel

___ 32. Sliding table

___ 33. Table dog

___ 34. Table-reversing lever

___ 35. Swivel table



Select the option which answers the question or completes the statement.

___ 36. How does the machinist determine if a grinding wheel is cracked?

a. Ring test it.
b. Test it with a ring.
c. Mount it on a grinder having a high rpm spindle.
d. Remove the blotter and check visually.
e. None of the above

___ 37. What must be on both sides of the grinding wheel before mounting on spindle?

a. Shoulders
b. Spacers
c. Blotters
d. Rubber discs
e. None of the above

___ 38. Which describes a waterlogged wheel?

a. Can be used for wet grinding
b. Could explode when started
c. Can be used when shoulder grinding
d. Both a and c
e. None of the above

___ 39. Before starting a grinder that has a grinding wheel already in place, what should be done?

a. Check wheel to see that it is securely mounted.
b. Rotate wheel by hand and check for obvious defects.
c. Make sure all guards are in place.
d. Position self out of wheel's path.
e. All of the above

___ 40. When ready to start the grinder, what should the operator do?

a. Stand to one side, out of the wheel's path.
b. Wait one full second after wheel is up to speed before using.
c. Clean safety glasses.
d. Ring-test wheel.
e. All the above

___ 41. When should safety glasses be worn?

a. When running a grinder
b. When operating any machine tool
c. At all times when in the shop area
d. When you feel it is necessary
e. None of the above

___ 42. What happens if a grinding wheel runs faster than its recommended speed?

a. It won't do as much useful work.
b. It will create chatter.
c. It will leave a rough finish.
d. Some wheels will shatter.
e. None of the above

___ 43. Which describes grinding dust in the shop?

a. Health hazard
b. Causes damage to other machines
c. Controlled by a vacuum collector
d. Safety hazard
e. All of the above

___ 44. Before being applied to the work, all newly installed wheels should be run at their full operating speed for at least how long?

a. Four
b. Three
c. Two
d. One
e. None of the above

___ 45. The safe working speed of a grinding wheel is given in what increments?

a. sfpm
b. mph
c. fpm
d. rpm
e. rps

ANSWERS TO UNIT TEST

1.	a	(K9)
2.	b	(K9)
3.	d	(K12)
4.	c	(K9)
5.	a	(K9)
6.	d	(K12)
7.	c	(K9)
8.	b	(K9)
9.	a	(K9)
10.	d	(K9)
11.	cd	(K9)
12.	ce	(K9)
13.	bd	(K9)
14.	bc	(K9)
15.	ad	(K9)
16.	b	(K9)
17.	c	(K9)
18.	e	(K9)
19.	de	(K9)
20.	ac	(K9)
21.	be	(K9)
22.	ae	(K9)
23.	ab	(K9)
24.	a	(K12)
25.	bd	(K12)
26.	ae	(K12)
27.	bc	(K12)
28.	be	(K12)
29.	ad	(K12)
30.	ac	(K12)
31.	e	(K12)
32.	c	(K12)
33.	d	(K12)
34.	ab	(K12)
35.	b	(K12)
36.	a	(K1)
37.	c	(K1)
38.	b	(K1)
39.	e	(K1)
40.	a	(K1)
41.	c	(K1)
42.	d	(K1)
43.	e	(K1)
44.	d	(K1)
45.	a	(K1)

MODULE: GRINDERS

UNIT II: SURFACE GRINDER ACCESSORIES AND EQUIPMENT MAINTENANCE

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to identify grinder accessories and proper equipment maintenance. The student should also be able to identify proper cutting fluid selection and applications. This knowledge will be evidenced through demonstration and by achieving the specified score on the unit test.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Match terms with definitions or illustrations.

1.2 Identify grinder accessories.

1.3 Identify proper equipment maintenance.

1.4 Identify proper cutting fluid selection and applications.

1.5 Clean and lubricate grinders and equipment. (competency K2, JS 1.1)

1.6 Select and apply cutting fluids. (competency K3, JS 1.2)

MODULE: GRINDERS

UNIT II: SURFACE GRINDER ACCESSORIES AND EQUIPMENT MAINTENANCE

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: ACCESSORIES AND MAINTENANCE

a. Information outline

b. Job sheets

JS 1.1: Clean and lubricate grinders and equipment
JS 1.2: Select and apply cutting fluids

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Harig, Herbert. Basic Precision Machining. Washington, DC: National Tool and Precision Machining Association, 1980.

2. Kibbe, Richard R., et. al. Machine Tool Practices. New York: John Wiley and Sons, 1979.

3. Krar, S. F. and J. W. Oswald. Grinding Technology. Albany, NY: Delmar Publishers, Inc., 1984.

4. Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987.

B. Curriculum guides

1. Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983.

2. Machinist. Frankfort, KY: Vocational-Technical Education Consortium of States, 1982.

3. Yettaw, Jerome. Vocational Machine Shop. University of Missouri-Columbia: Instructional Materials Laboratory, 1977.

C. Manual

1. Operation and Maintenance Manual of the 618 and 818 Micromaster Series II Surface Grinding Machines. North Kingstown, RI: Brown and Sharpe Co., 1980.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Show students surface grinder accessories, maintenance supplies and coolant systems in the shop.

2. Demonstrate proper cleaning and lubrication techniques.

3. Demonstrate the proper method of selecting and applying cutting fluids.

B. Suggested supplemental materials

1. Introduction to the Surface Grinder (MS-84-370) (video). Sedalia, MO: State Fair Community College, 1984. (Available for purchase from SFCC; available for loan from Missouri Vocational Resource Center, phone 800/392-7217 or 314/882-9610)

2. Operation and Maintenance Manual of the 618 and 818 Micromaster Series II Surface Grinding Machines. North Kingstown, RI: Brown and Sharpe Co., 1980.

3. Oberg, Erik; Franklin D. Jones; Holbrook L. Horton. Machinery's Handbook. 23rd ed. New York: Industrial Press, Inc., 1988.

MODULE: GRINDERS

UNIT II: SURFACE GRINDER ACCESSORIES AND EQUIPMENT MAINTENANCE

LESSON 1: ACCESSORIES AND MAINTENANCE

I. Terms and definitions

A. Abrasive stick--an aluminum oxide, silicon carbide or cubic boron nitride abrasive used for off-hand dressing a grinding wheel

B. Balancing---adding, subtracting or positioning weights on grinding wheel hub so that wheel weight will be evenly distributed

C. Burr--turned-over edge of metal caused by grinding operation

D. Cutter--part of grinding wheel dresser that comes into contact with wheel and does the dressing or shaping

E. Cutting fluid--liquid which keeps heat from generating on workpiece or grinding wheel; also lubricates surfaces and increases cutting performance

F. Dressing--process to improve or alter cutting action of grinding wheel

G. Generated heat--increased temperature of workpiece and wheel caused by grinding friction

H. Glazing--dulling of grinding wheel cutting particles; results in decreased cutting efficiency

I. Honing--operation using bonded abrasive stick in special holder to remove stock and produce a desired surface accurately

J. Loaded--condition of grinding wheel in which the pores are filled with material being ground; results in poor finish on workpiece and reduces cutting action of the wheel

K. Lubricant--oil used to keep machine surfaces from building up friction and heat

L. Medium--solution used to carry or suspend particles during lapping operations; plural, media

M. Operating or wheel speed--speed of revolving grinding wheel expressed in revolutions per minute (rpm) or surface feet per minute (sfpm)

N. Profilometer--instrument for measuring the degree of surface roughness in micro-inches (.000001 inch)

O. Scale--black layer on surface of steel that has been heat-treated or formed hot; must be removed before grinding

P. Solvent--liquid degreaser or cleaner used to wipe down machine surfaces or accessories

Q. Sump--container which holds cutting, lubricating or hydraulic fluid

R. Traverse rate--rate of grinding wheel movement across workpiece

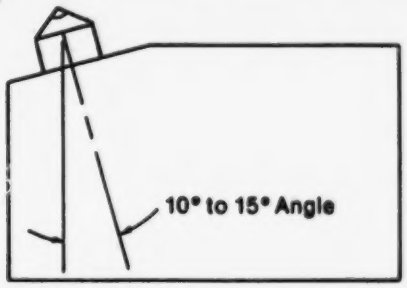
S. Work speed--rate at which workpiece or table traverse moves; measured in feet per minute

II. Surface grinder accessories

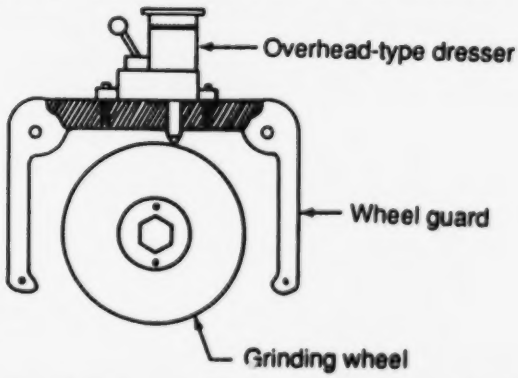
A. Grinding wheel dressers

1. Single-point mounted diamond held in holder; holder mounted directly to magnetic chuck

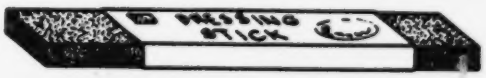
Art credit for the next three drawings: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 115-116. Used by permission.



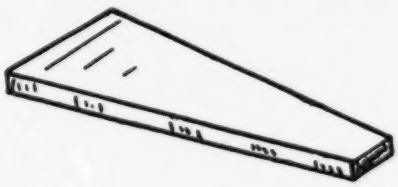
2. Single-point mounted diamond held in overhead-type dresser which is permanently mounted to wheel guard; dresses periphery of grinding wheel flat



3. Abrasive stick--hand-held dresser used to remove ragged edges from grinding wheel; also used for rough forming or shaping

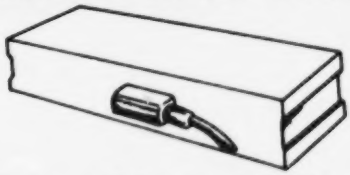


4. Angle gage block--steel block with required angle placed on magnetic chuck; used to set support block and mounted diamond to dress wheel edge angle

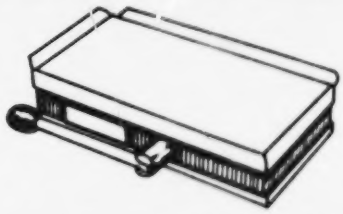


B. Work-holding devices

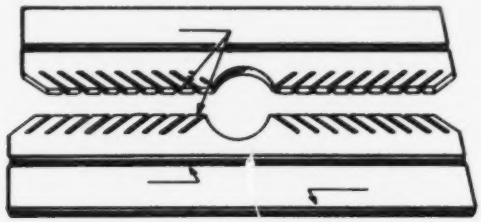
1. Electromagnetic chuck--electromagnetic forces controlled by an on-off position switch; ferrous metal workpieces held directly on the face or by using other accessories



2. Permanent magnetic--magnetic forces controlled by lever located on the side of the chuck; ferrous metal workpieces and other accessories also held directly on the face of the chuck

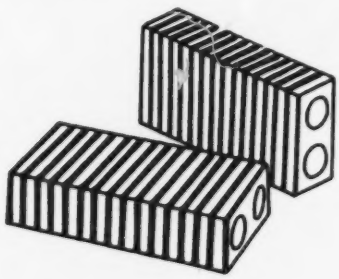


3. Magna-vise (permanent) clamps--flexible, comb-like, thin, flat bar attached to a solid bar by a spring-steel hinge; holds non-metallic workpieces that do not have a large bearing surface.



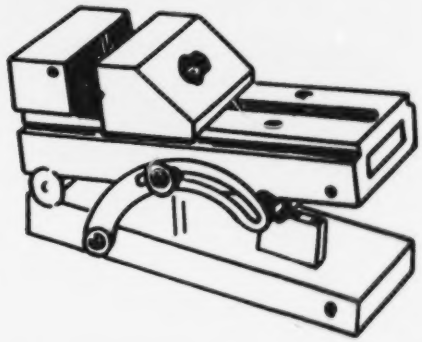
4. Laminated plates, parallels and blocks--low carbon steel alternated with thin separators (spacing strips)

NOTE: Sometimes referred to as kinetic plates, parallels and V-blocks

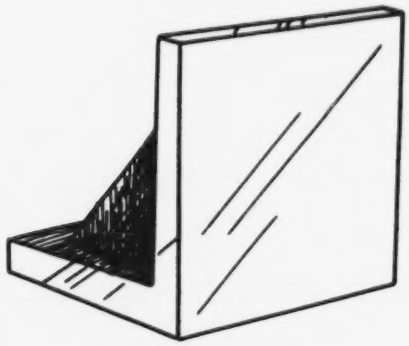


5. Simple sine vise--a precision base with movable sine plate and two hardened precision rolls; used to set and hold single angles which lie in one plane

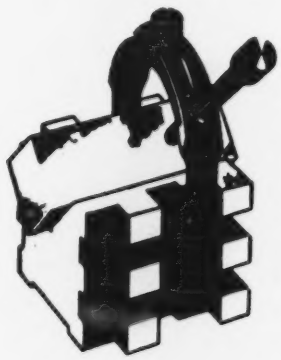
Art credit for the next four drawings: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 120-123. Used by permission.



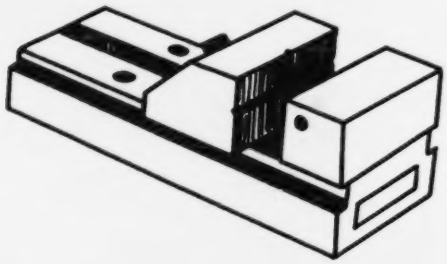
6. Angle plate--a precision ground, 90-degree steel block placed on magnetic chuck; used to support workpiece



7. V-block and clamp--support cylindrical workpieces during set-up, manufacture or inspection. The 90° V is centered and parallel to the bottom face. The V is machined square (perpendicular) to the two ends.



8. Vise (precision)--precision ground steel; holding device which clamps the workpiece directly and is mounted to magnetic chuck



9. Clamps

   a. "C" clamp--C-shaped frame which has one adjusting screw that runs through one end of the frame; also used when larger parts are to be secured

   b. Parallel clamp--generally used on set-ups to clamp parts with flat surfaces. The flat surface of the jaws prevent scarring of the workpiece.

C. Precision measuring and set-up equipment

1. Surface plate--a cast iron, semi-steel or granite plate which is ground to an extremely flat finish. The plate is essential to set-up and grinding inspection as it provides a true reference base or datum.

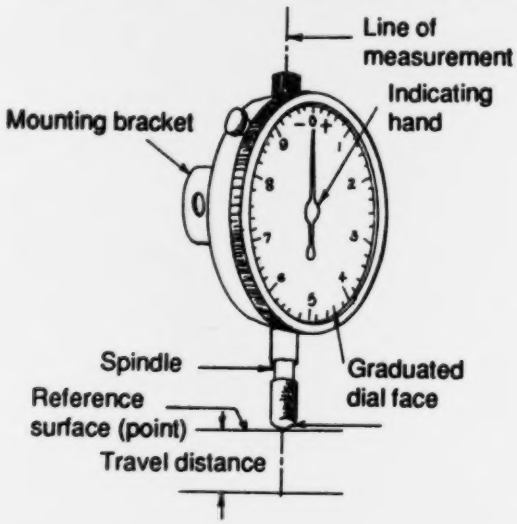
2. Parallels--strips of steel hardened by heat treatment. The sides are machined parallel with great accuracy. In grinding operations, they are used separately or in pairs for supporting work parallel to a reference surface.

3. Outside and depth micrometers--precision tools used to measure linear distances of holes, shoulders, recesses and grooves. Micrometers have an accuracy of .001 inch or .0001 inch.

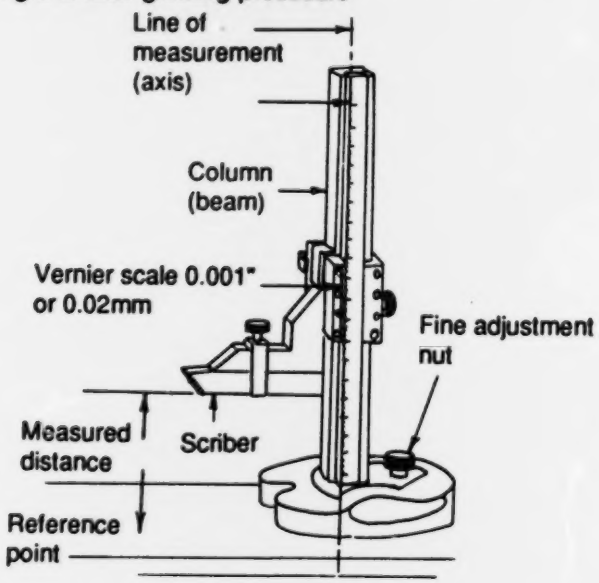
4. Dial indicator--mechanism that multiplies the movement of a contact point

   a. To measure a length (distance between a standard dimension to which the dial indicator is pre-set)

b. To directly measure how much a feature of the workpiece is out of true



5. Vernier height gage--instrument used in conjunction with the surface plate; dial indicator and holding device; used for taking measurements or checking accuracy of workpiece during and after grinding procedure



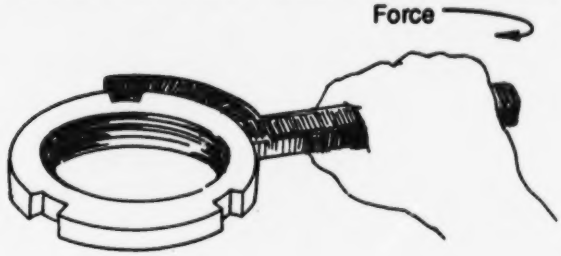
D. Hand tools

1. Spanner wrenches

a. Face spanner--has pins that fit into notches or holes to remove nuts that draw or hold the wheel chuck or other device securely.

NOTE: A reverse turning process unlocks the chuck so that it can be removed.

b. Single-end (hook) spanner--used to turn a special nut or bolt that is notched



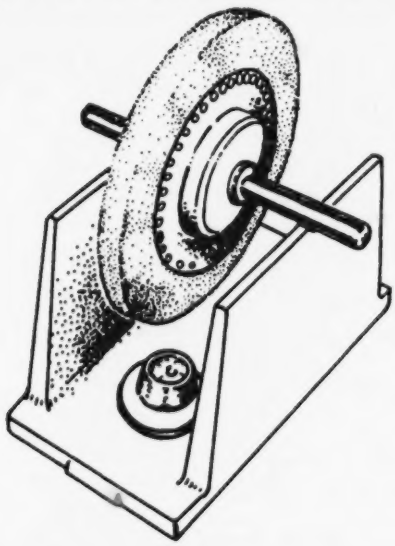
2. Squeegee--rubber-edged, surface cleaning tool used to wipe coolant and debris from the face of the magnetic chuck.

   NOTE: Often the wheel has to remain running when setting up and grinding a workpiece. The squeegee allows the operator to keep hands out of the danger zone.

3. Single-cut file--(second cut) a smooth-cut file used for finish cutting or preparing a workpiece when mounting onto the workholding device.

4. Oil stone--natural or manmade abrasive used to burr, cut and polish hard metals to produce keen, smooth edges.

5. Parallel balancing ways--consist of two parallel knife-edge surfaces which are part of a solid frame. A grinding wheel is mounted with its adapter and balancing arbor, then placed on the balancing ways; the wheel comes to rest on its heavy spot on the under side of the arbor.



III. Guidelines for equipment maintenance procedures

A. Read and follow all grinder manufacturer's recommendations.

B. Know where main power switch is located and turn off power before cleaning or maintaining grinder.

C. Always remove all accessories from grinder before cleaning. (This excludes the magnetic chuck.)

D. When removing metal chips, abrasive dust and grease, use brush or cloth only. (Never use compressed air to clean the grinder--damage could result to precision ways or operator's eyesight.)

E. Use only recommended solvent-soaked cloth when wiping down grinder.

F. All accessories, hoses and tools should be wiped down with recommended solvent-soaked cloth.

NOTE: Clean precision measuring tools with a dry cloth only.

G. Using recommended lubricant, lubricate grinder according to manufacturer's specifications.

H. If necessary, replace or refill cutting fluid to proper sump reservoir level.

I. Inspect grinder and grinding area; reclean any necessary areas.

J. Secure dustpan and broom, sweep area clean and carefully discard refuse.

K. Return all tools, accessories and cleaning equipment; store in proper location.

L. Inspect spindle oil each day and maintain at proper level.

M. Brush or vacuum abrasive particles and metal from grinding machine.

NOTE: Never use compressed air; damage to grinder will result.

N. Clean coolant tank and replace coolant when necessary.

O. Keep grinding machine balanced and level.

P. Check belt condition and tension. Replace or adjust as needed.

Q. Clean table or work-holding device each time machine is operated.

IV. Grinding fluids and coolant systems

A. Three basic types of cutting fluids

1. Water-soluble chemical--used on medium to heavy stock removal processes; transparent with excellent cooling properties

2. Water-soluble oil--combines the cooling qualities of water and the lubricating advantages of oil. The oil-water fluids form a milky solution. An emulsifying agent is added.

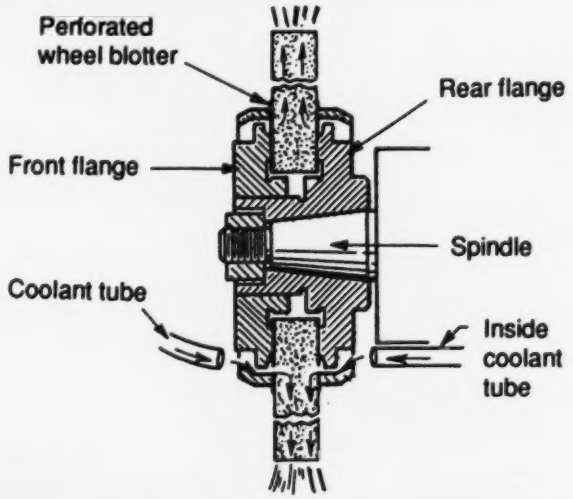
CAUTION: Additives must be controlled. Skin irritation or infection can result from a too-strong disinfectant solution.

3. Straight oil-grinding fluids--most costly of the three fluids. These fluids provide excellent lubrication but are not as effective as the water-soluble fluids to dissipate heat. They are used primarily on very hard materials to lengthen wheel life and give high dimensional accuracy and surface finish.

NOTE: Oil grinding fluids are most practical in thread and other heavy form-grinding operations.

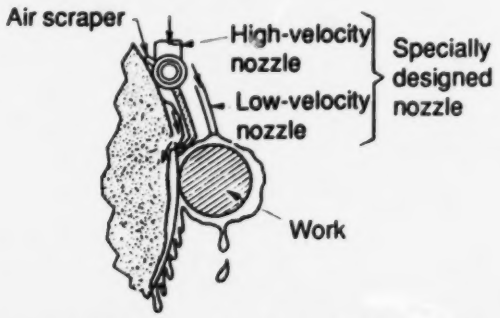
B. Three principal coolant systems in wet grinding

1. Flood through-the-wheel--grinding fluid pumped through the two side-mounted coolant tubes. The centrifugal force of the revolving wheel carries fluid to the wheel periphery and flushes chips and particles for a cool cutting action.



Art credit for the next two illustrations: Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987, pg. 505-506.

2. Flood coolant--grinding fluid pumped from a reservoir through a nozzle to the work area, then recirculated through the system. The use of two or more nozzles helps decrease generated heat during alternating grinding passes.



3. Mist coolant--this system works on an atomizer principle where a small volume of liquid is atomized into a large mass of pressurized air and the coolant emerges from the nozzle as a mist. Cooling action is produced by the air, and material and vapor evaporation is blown from the grinding area.

C. Mixing water-soluble oil grinding fluids

NOTE: If the mixture is too weak, it may cause corrosion of both work and machine surfaces.

1. Read and follow all grinder manufacturer's recommendations.

2. Secure necessary measuring cups, buckets or containers.

3. Mixture could range from one part soluble oil and five parts water to one part soluble oil and 50-100 parts water.

4. Soluble oils are easily mixed, but since the emulsion is of the oil-in-water type, it should always be prepared by pouring the oil into the water instead of pouring water into oil.

5. Commonly, one pint of soluble oil is mixed with five gallons of water; this amount will usually replace or refill the reservoir of a standard coolant system.

6. There are no fixed rules or formulas for selecting cutting fluids, except the rule of an actual test with material and a given tool or operation.

7. Considerations when selecting and applying cutting fluids

   a. Hygienic properties (to prevent dermatitis on the hands and face of machine operators)

   b. Toxicity of the cutting fluid

   c. Possibility of bacterial growth which causes unpleasant odors

   d. Ease of handling, preparation and concentration

   e. Ability to resist foaming, smoking and misting

   f. Service life and cost

8. Return containers and cups to proper locations.

CLEAN AND LUBRICATE GRINDERS AND EQUIPMENT

Equipment:

Grinding machine
Manufacturer's specifications
Proper solvent cleaner
Clean, absorbent cloth
Brush
Recommended lubricant
Eye protection
Broom and dustpan
Hand tools
Wrenches

INSTRUCTOR'S NOTE: For this evaluation, a grinder should be provided with the grinding wheel removed.

Procedure:	Evaluation 3	2	1	N
1. Obtain manufacturer's specifications for grinder.	—	—	—	—
2. Turn off power. Remove all accessories from grinder except for the magnetic chuck.	—	—	—	—
3. Remove chips and abrasive particles with brush or cloth.	—	—	—	—
4. Wipe down machine, hoses and grinder accessories with cloth soaked with proper cleaning solvent.	—	—	—	—
5. Lubricate grinder according to manufacturer's specifications. Inspect grinder.	—	—	—	—
6. Sweep area clean and carefully discard refuse. Return tools, accessories and equipment to proper location.	—	—	—	—
Average of above evaluations*	—	—	—	—

*This average is the student's final evaluation for competency K2: Clean and lubricate grinders.

SELECT AND APPLY CUTTING FLUIDS

Equipment:

Measuring cup
Five-gallon container
Water-soluble cutting fluid
Stir paddle
Pour funnel

INSTRUCTOR'S NOTE: This activity can be performed on any grinding machine and may be delayed according to needed maintenance schedule.

Procedure:	Evaluation 3	2	1	N
1. Obtain manufacturer's specifications for grinder. Turn off power/unplug machine.	—	—	—	—
2. Obtain five-gallon coolant container and measuring cup. If required, disconnect sump pump drain hose and wipe out reservoir with proper cloth or brush.	—	—	—	—
3. Measure oil-soluble solution. Mix coolant.	—	—	—	—
4. Using funnel, pour cutting fluid into reservoir to proper level and replace reservoir drain hose.	—	—	—	—
5. Turn on power/plug in machine.	—	—	—	—
6. Return all containers, measuring cups and tools to proper area. Wipe up any spills, sweep area and carefully discard refuse.	—	—	—	—
Average of above evaluations*	—	—	—	—

*This average is the student's final evaluation for competency K3: Select and apply cutting fluids.

MODULE: GRINDERS

UNIT II: SURFACE GRINDER ACCESSORIES EQUIPMENT MAINTENANCE

UNIT TEST

Match the following terms and definitions.

____ 1.	Dulling of grinding wheel cutting particles; results in decreased cutting efficiency	a. Loaded
____ 2.	Turned-over edge of metal caused by grinding operation	b. Profilometer
____ 3.	Rate at which workpiece or table traverse moves; measured in feet per minute	c. Balancing
____ 4.	Process to improve or alter cutting action of grinding wheel	d. Work speed
____ 5.	Increased temperature of workpiece and wheel caused by grinding friction	e. Glazing
____ 6.	Adding, subtracting or positioning weights on grinding wheel hub so that wheel weight will be evenly distributed	ab. Traverse rate
____ 7.	Operation using bonded abrasive stick in special holder to remove stock and produce a desired surface accurately	ac. Burr
____ 8.	Condition of grinding wheel in which the pores are filled with material being ground; results in poor finish on workpiece and reduced cutting action of wheel	ad. Generated heat
____ 9.	Speed of revolving grinding wheel expressed in revolutions per minute (rpm) or surface feet per minute (sfm)	ae. Medium
____ 10.	Solution used to carry or suspend abrasive particles during lapping operations	bc. Dressing
____ 11.	Black layer on steel surface that has been heat-treated or formed hot; must be removed before grinding	bd. Cutter
____ 12.	Rate of grinding wheel movement across workpiece	be. Honing
____ 13.	Part of grinding wheel dresser that comes into contact with wheel and does the dressing or shaping	cd. Scale
____ 14.	Instrument for measuring the degree of surface roughness in micro-inches (0.000001 inch)	ce. Operating or wheel speed

Match the following terms and definitions.

____ 15. Used to keep generated heat from workpiece or grinding wheel

____ 16. Used to keep machine surfaces from building up friction and heat

____ 17. Used for off-hand dressing of a grinding wheel

____ 18. Liquid degreaser or cleaner used to wipe down machine surfaces or accessories

a. Abrasive stick
b. Cutting fluid
c. Lubricant
d. Solvent
e. Sump

Match the letter on the grinder accessory with the term for the part in the list below.

____ 19. Angle gage block

____ 20. Single-point mounted diamond in overhead type dresser

____ 21. Permanent magnetic

____ 22. Laminated parallels

____ 23. Single-point mounted diamond in holder

____ 24. Magna-vise (permanent) clamps

____ 25. Abrasive stick

____ 26. Electro magnet

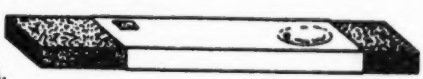
____ 27. Simple sine vise

____ 28. Vise (precision)

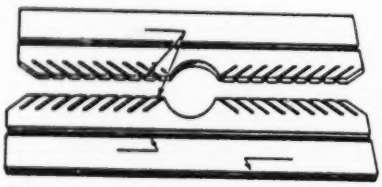
____ 29. Angle plate

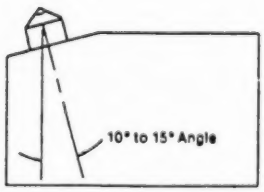
____ 30. Dial indicator

A.



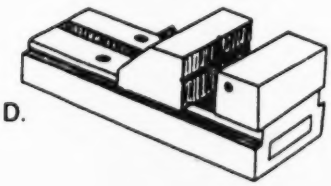
B.

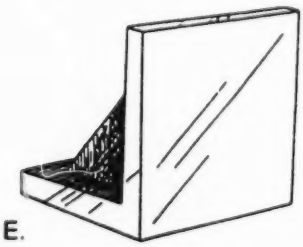




C.

D.





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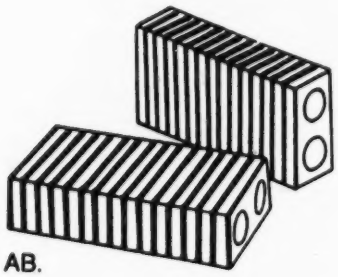
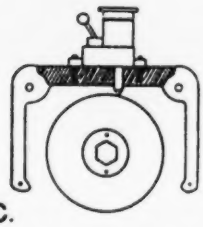
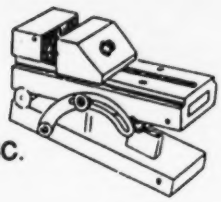


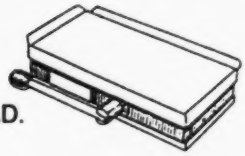
AB.



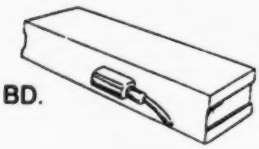
AC.



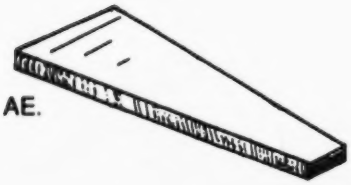
BC.



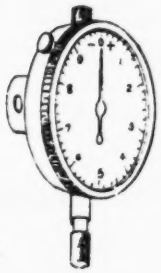
AD.



BD.



AE.



BE.

Each of the following maintenance and fluid selection test items or incomplete statements is followed by four suggested answers or completions. Select the one which is best in each case.

___ 31. What is used to lubricate the grinder's moving parts?

a. Soluble oil
b. Lard oil
c. Lubrication oil
d. 10-W40
e. None of the above

___ 32. What should be used to clean the grinder?

a. Air pressure
b. Paint remover
c. Soap and water
d. Clean rags and solvent
e. None of the above

___ 33. Which of the following should <u>not</u> be done when cleaning the grinding machine?

a. Use liquid around electrical wiring or switches.
b. Shut off power to the machine.
c. Store tools and accessories in their proper location.
d. Remove accessories before cleaning.
e. All of the above

___ 34. How does the operator find the proper type and amount of lubrication?

a. Refer to operator's manual or lubrication chart.
b. Refer to glossary.
c. Look on the back of machine.
d. Ask another student.
e. None of the above

___ 35. The grinder should not be cleaned by which method?

a. Solvent
b. Compressed air
c. Brush or vacuum
d. Rags
e. None of the above

___ 36. How often should the spindle oil be checked?

a. Daily
b. Weekly
c. Monthly
d. Hourly
e. None of the above

___ 37. What is coolant used for on most grinding operations?

a. Help keep the part from overheating
b. Flush spent abrasive grains from workpiece
c. Act as a rust inhibitor
d. Help overcome effects of friction
e. All of the above

___ 38. Which of the following is not a type of cutting fluid used in grinding?

a. Mineral oil
b. Water-soluble oil
c. Water-soluble chemical
d. Straight oil
e. All of the above

___ 39. Which of the following is not a method of delivering grinding fluid to the workpiece and cutting area?

a. Flood
b. Flood through-the-wheel
c. Mist
d Vacuum
e. None of the above

___ 40. What happens to the work and machine surface if the mixture of cutting fluid is too weak?

a. May corrode
b. Will shatter
c. Becomes welded together
d. Softens
e. None of the above

___ 41. Select the most common oil-to-water ratio.

a. One pint oil to five gallons water
b. One part oil to one part water
c. Five parts oil to 150 parts water
d. 10 parts oil to 10 parts water
e. None of the above

___ 42. What hygienic considerations should be made when selecting and applying cutting fluids?

a. Dandruff
b. Dehydration
c. Dermatitis
d. Delirium
e. All of the above

ANSWERS TO UNIT TEST

1.	e	(K2)
2.	ac	(K2)
3.	d	
4.	bc	(K3)
5.	ad	(K3)
6.	c	(K5)
7.	bc	
8.	a	(K2)
9.	ce	
10.	ae	(K3)
11.	cd	
12.	ab	
13.	bd	(K3)
14.	b	
15.	b	(K2)
16.	c	(K2)
17.	a	
18.	d	(K2)
19.	ae	
20.	ac	
21.	ad	
22.	ab	
23.	c	
24.	b	
25.	a	
26.	bd	
27.	bc	
28.	d	
29.	e	
30.	be	
31.	c	(K2)
32.	d	(K2)
33.	a	(K2)
34.	a	(K2)
35.	b	(K2)
36.	a	(K2)
37.	e	(K2)
38.	a	(K2)
39.	d	(K2)
40.	a	(K2)
41.	a	(K2)
42.	c	(K2)

MODULE: GRINDERS

UNIT III: SURFACE GRINDER PREPARATION AND SET-UP

UNIT OBJECTIVE

Upon completion of this unit the student should be able to identify grinding wheels and proper set-up techniques. The student should also be able to dress and true a grinding wheel. This knowledge will be evidenced through demonstrations and by achieving a specified score on the unit test.

SPECIFIC OBJECTIVES

After completion of the lessons on this unit, the student should be able to:

1.1 Match terms with definitions or illustrations.

1.2 Identify types of grinding wheels.

1.3 Identify proper set-up techniques and considerations.

1.4 Inspect grinding wheel. (competency K4, JS 1.1)

1.5 Select and mount grinding wheel. (competency K6, JS 1.2)

1.6 Balance grinding wheel using a mandrel. (competencies I34 and K5, JS 1.3)

2.1 Identify dressing and truing techniques.

2.2 Identify relieving and side dressing techniques.

2.3 Identify angle dressing using angle gage block.

2.4 Dress and true grinding wheel. (competency K7, JS 2.1)

MODULE: GRINDERS

UNIT III: SURFACE GRINDER PREPARATION AND SET-UP

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: ACCESSORIES AND SET-UP

   a. Information outline

   b. Transparencies

      TM 1.1: Grinding wheel shapes
      TM 1.2: Mounting grinding wheels

   c. Handouts

      HO 1.1: Symbols used when selecting grinding wheels
      HO 1.2: Common problems and actions
      HO 1.3: Conversion of surface speeds to spindle speeds

   d. Assignment sheet

      AS 1.1: Interpret grinding wheel markings

   e. Answers to assignment sheet

   f. Job sheets

      JS 1.1: Inspect grinding wheel
      JS 1.2: Select and mount grinding wheel
      JS 1.3: Balance grinding wheel using a mandrel

2. Lesson 2: DRESSING AND TRUING WHEELS

   a. Information outline

   b. Transparency

      TM 2.1: Truing, dressing and balancing

   c. Job sheet

      JS 2.1: Dress and true grinding wheel

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Harig, Herbert. Basic Precision Machining. Washington, DC: National Tool and Precision Machining Association, 1980.

2. Kibbe, Richard R., et. al. Machine Tool Practices. New York: John Wiley and Sons, 1979.

3. Krar, S. F. and J. W. Oswald. Grinding Technology. Albany, NY: Delmar Publishers, Inc., 1984.

4. Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987.

B. Curriculum guides

1. Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983.

2. Machinist. Frankfort, KY: Vocational-Technical Education Consortium of States, 1982.

3. Yettaw, Jerome. Vocational Machine Shop. University of Missouri-Columbia: Instructional Materials Laboratory, 1977.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Show students types of grinding wheels, parts of wheels and markings. Demonstrate proper methods when inspecting, mounting and balancing wheels.

2. Demonstrate proper dressing and truing techniques.

B. Suggested supplemental materials

1. Operation and Maintenance Manual of the 618 and 818 Micromaster Series II Surface Grinding Machines. North Kingstown, RI: Brown and Sharpe Co., 1980.

2. Oberg, Erik; Franklin D. Jones; Holbrook L. Horton. Machinery's Handbook. 23rd ed. New York: Industrial Press, Inc., 1988.

MODULE: GRINDERS

UNIT III: SURFACE GRINDER PREPARATION AND SET-UP

LESSON 1: ACCESSORIES AND SET-UP

I. Terms and definitions **(HO 1.1)**

A. Abrasive--grinding wheel material that acts as the cutting agent

B. Arbor--the main shaft of a machine. In grinding, the shaft on which the wheel is held.

C. Bond--material that holds abrasive together; designated as a letter or letters and/or numbers

D. Cross-feed--transverse feed; movement of machine head or table at right angles to the operator or machine axis/column

E. Dressing--a method of preparing the grinding wheel by exposing new, sharp cutting grains; also maintains the wheel form

F. Face--the surface of the grinding wheel at the outermost diameter

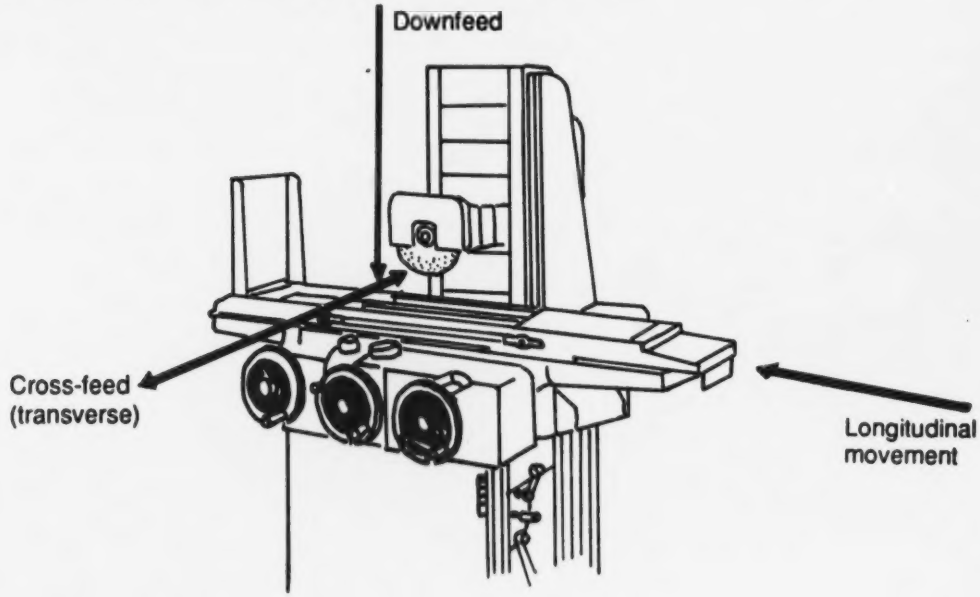
G. Finish grinding--final grinding operation to improve dimensional accuracy and obtain desired or near-desired finish

H. Grade--strength of the bond that holds wheel abrasives together; expressed as a letter

I. Gram or grit--size of abrasive; expressed as a number

J. Lapping--finishing process that uses loose abrasive grains carried by a medium to produce a desired surface finish

K. Longitudinal--reciprocating movement of the table right and left



L. Periphery--the outermost dimension of the wheel; may be considered the side of wheel if dish wheel or dish is employed

M. Rough grinding--first grinding operation to reduce stock rapidly without particular regard to finish produced

N. sfpm--surface feet per minute

O. Structure--grain spacing; designated by open or closed

P. Truing--an operation that is carried out on all newly mounted wheels; the removal of material from the cutting face of the wheel so that the surface runs concentric to the spindle axis

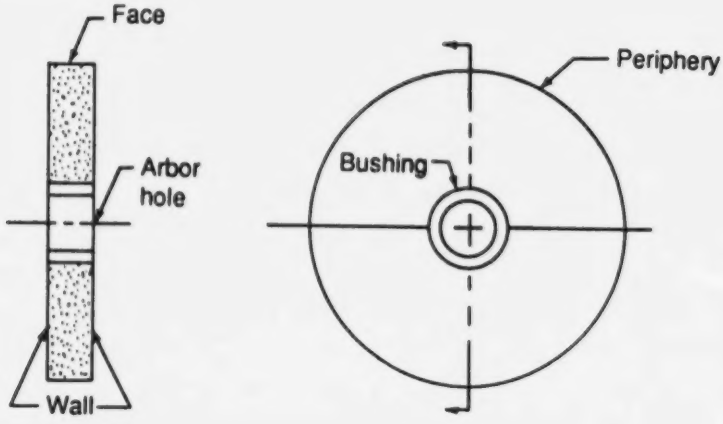
Q. Work feed--rate wheel is fed into workpiece each time table reverses

R. Wheel speed (rpm)--grinding wheel revolutions per minute

II. Types and applications of grinding wheels **(TM 1.1)**

A. Type #1 straight wheel uses

1. Surface grinding
2. Internal grinding
3. Cylindrical grinding
4. Offset grinding



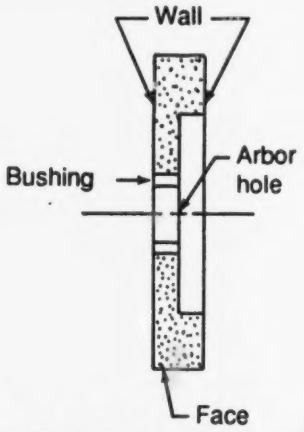
Credit for this lesson's artwork: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 6-9. Used by permission.

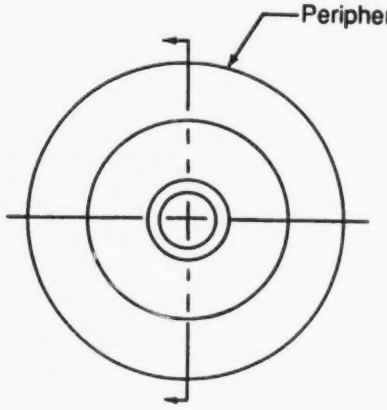
B. Type #5 straight wheel/recessed one side uses

1. Surface grinding
2. Cylindrical grinding

3. Off-hand grinding

NOTE: Wheel is recessed so that greater wheel thickness can be used for increased strength.

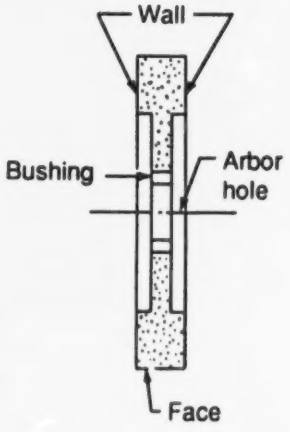


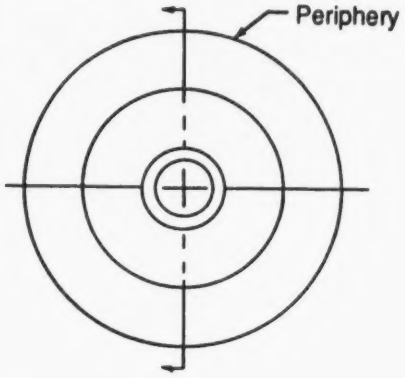


C. Type #7 straight wheel/recessed both sides

1. Surface grinding

2. Cylindrical grinding

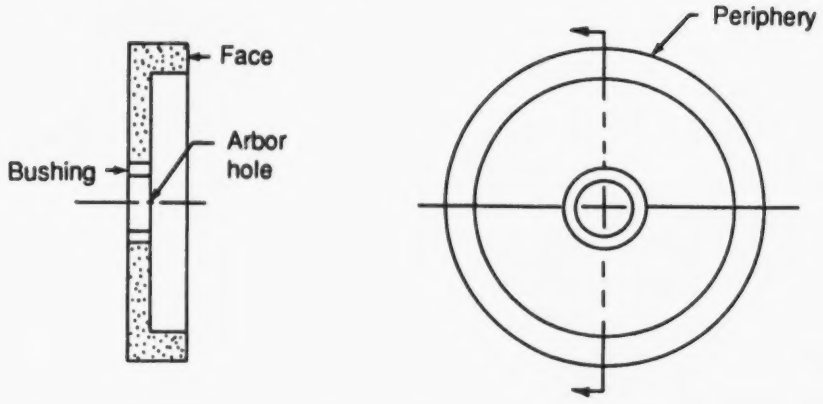




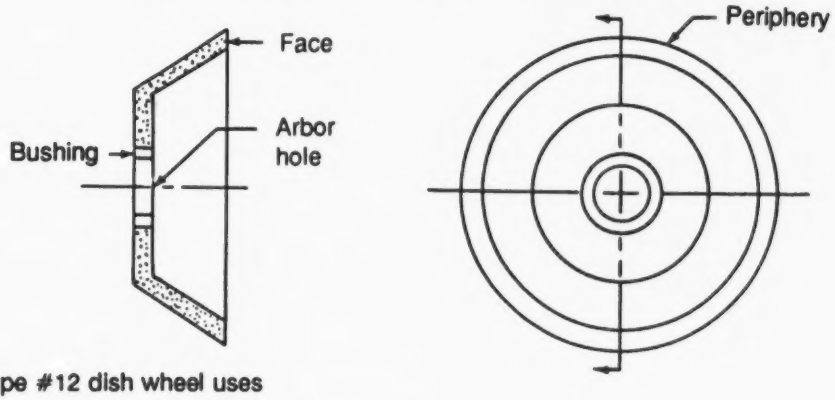
D. Type #6 straight cup wheel uses

1. Cutter grinding
2. Vertical spindle grinding

NOTE: Designed for side grinding

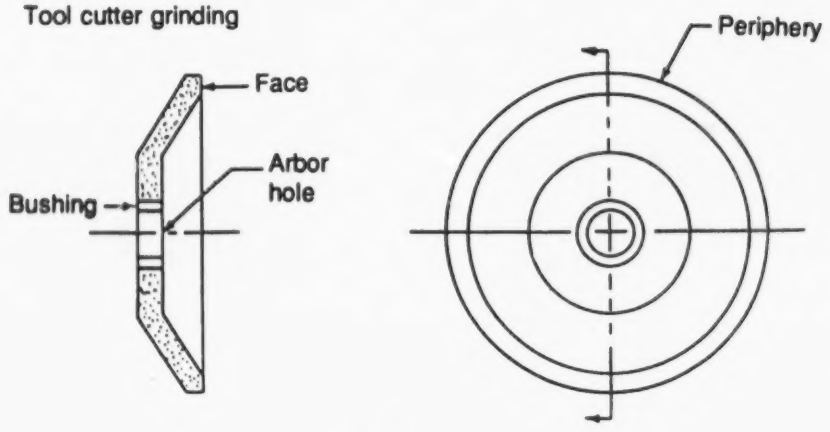


E. Type #11 flaring-cup wheel--used primarily for tool and cutter grinding



F. Type #12 dish wheel uses

1. Tool room grinding
2. Tool cutter grinding



NOTE: May be used for periphery or side grinding in narrow places

III. Proper set-up techniques and considerations **(TM 1.2, HO 1.2, HO 1.3)**

A. Material to be ground

1. With hard material, a softer grade of wheel is required.

2. With soft material, a harder grade of wheel is required.

3. Consult the manufacturer's recommendations for choice of abrasive, grain, size, grade and band of wheel for specific requirements.

B. Material to be removed

1. For roughing out or rapid removal, use a coarse-grained, open structured wheel.

2. Open structured, coarse-grained wheel is also good for batch operations and interrupted cuts.

C. Surface finish

1. Finish depends on the size of grit employed.

2. On precision grinding, proper truing and dressing can maintain the finish without sacrificing metal removal rate.

3. Usually, fine grit wheels are used.

D. The greater the **wheel contact** with the workpiece, the softer the grade of wheel required.

E. Speeds and feeds

CAUTION: Where wheel speeds can be increased, the grinding wheel manufacturer's recommendations must not be exceeded.

1. For roughing out, use low work speed/heavy infeed/fast longitudinal movement.

2. Use high work speed/light infeed to cool fragile work.

3. If wheel acts hard and glazed, use higher work speed and longitudinal speed.

4. If wheel acts soft and wears rapidly, use lower work speed and longitudinal speed. (Experience will show that a grinding wheel can be made to act harder or softer by variations in work speed, wheel speed, longitudinal rate or infeed rate.)

F. Inspection of the grinding wheel

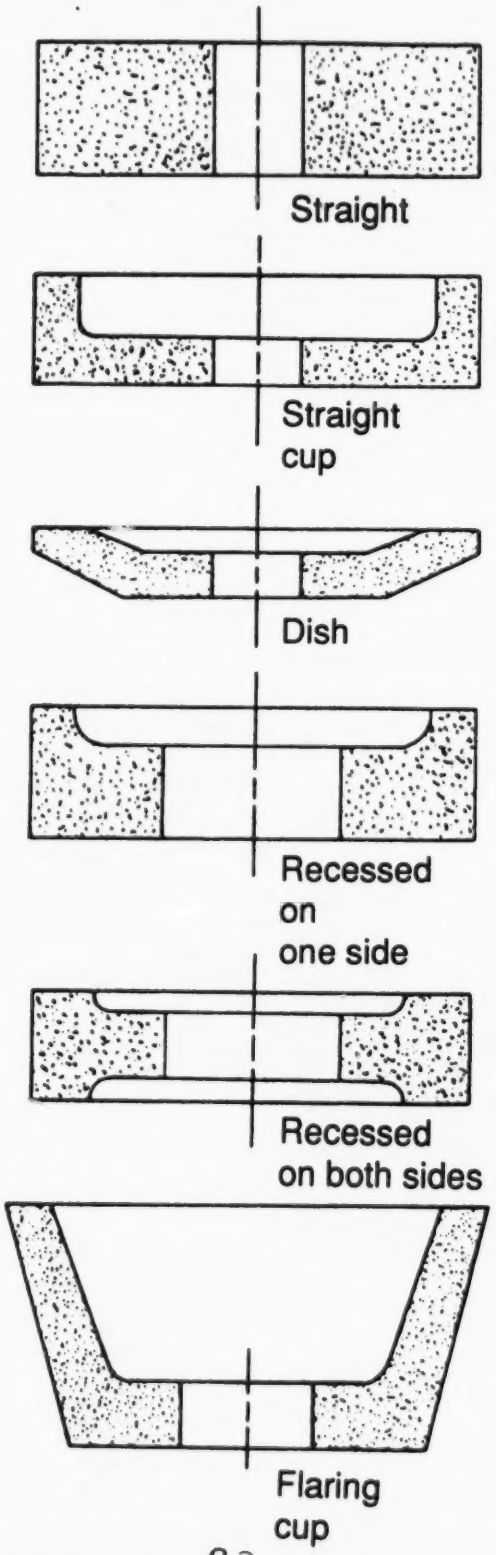
1. Visually check wheel for cracks and ensure that bushing (if used) does not extend beyond the side of wheel.

2. Ring test wheel--Balance the wheel between fingers through bore and tap with non-metallic instrument such as a screwdriver handle or hide end of a hammer. If wheel is undamaged, it will give a clear ring. If you detect a damaged wheel or note interference size, notify your supervisor.

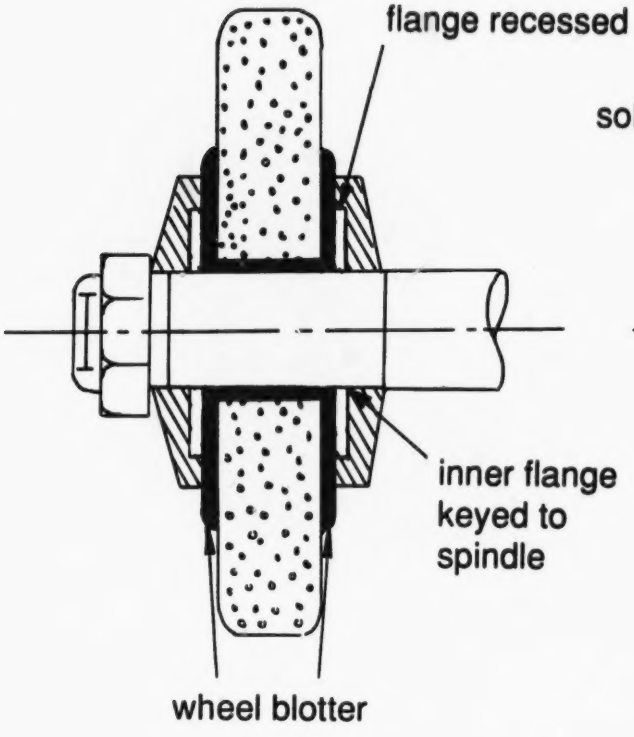
CAUTION: Never mount a wheel that does not give a clear ring. Do not use it. Also, never mount a wheel without blotters; the clamping pressure may crack the wheel.

3. Wheel should be correct for machine being used.

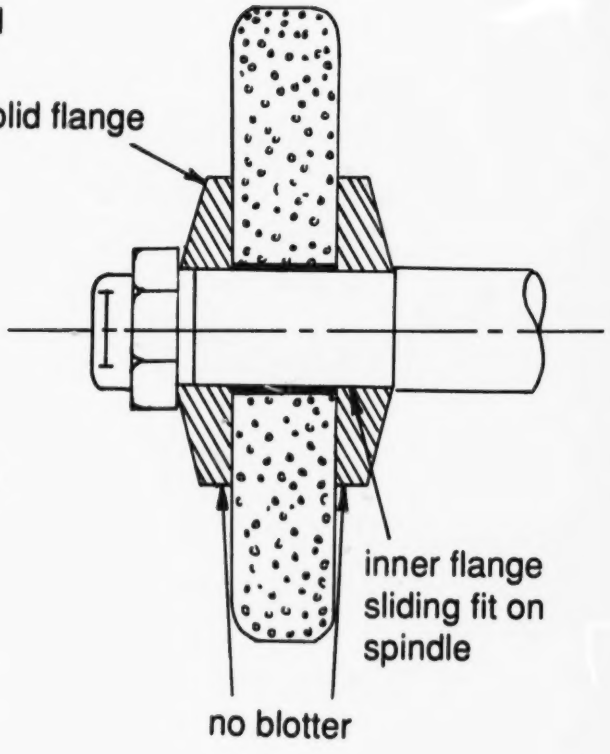
GRINDING WHEEL SHAPES



MOUNTING GRINDING WHEELS

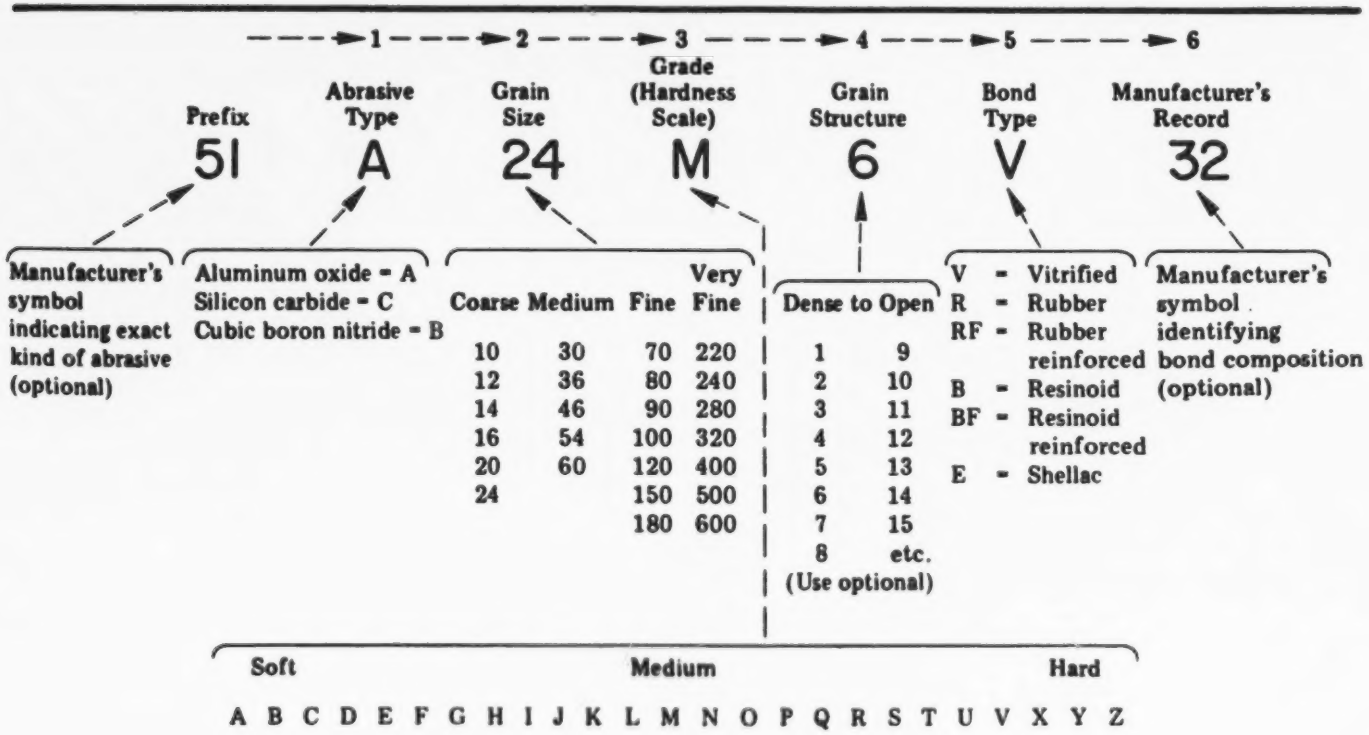


Correctly Mounted Wheel



Improperly Mounted Wheel

SYMBOLS USED WHEN SELECTING GRINDING WHEELS



Credits: American National Standards Institute

Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987, pg. 423.

COMMON PROBLEMS AND ACTIONS

Probable Cause and/or Corrective Action	Grinding Problem										
	Surface Texture					Dimensional Accuracy			Operating Conditions		
									Wheel		Spindle
	Chatter Marks	Scratches	Spiral Marks	Burning/Checking	Burnishing	Not Ground Flat	Out-of-Parallel or round	Not Sizing Uniformly	Loading	Glazing	Spindle Running Too Hot
Grinding Wheel											
Grain size											
Too fine				X	X				X	X	
Too coarse		X									
Structure											
Too dense				X					X	X	
Too hard	X			X	X	X			X	X	
Grade too soft	X	X									
Dressing too fine				X		X			X	X	
Out-of-balance	X										
Dull, glazed, loaded	X			X							
Not trued properly	X	X									
Speed too high				X							
Workpiece											
Work speed too slow				X							
Out-of-balance	X										
Not adequately supported	X										
Centers worn or require lubrication	X						X	X			
Insufficient number or improper adjustment of back rests	X						X	X			
Work speed or table travel too high	X	X									

Credit: Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987, pg. 426.

CONVERSION OF SURFACE SPEEDS TO SPINDLE SPEEDS

Wheel Diameter (mm)	Surface Speed in Feet per Minute (sfpm)										Wheel Diameter (Inches)
	4,000	4,500	5,500	6,500	7,500	9,500	12,500	14,200	16,000	17,000	
	Spindle Speeds in Revolutions per Minute (RPM)										
25.4	15,279	17,189	21,008	24,828	28,647	36,287	47,745	54,240	61,116	64,935	1
50.8	7,639	8,594	10,504	12,414	14,328	18,143	23,875	27,120	30,558	32,465	2
76.2	5,093	5,729	7,003	8,276	9,549	12,096	15,915	18,080	20,372	21,645	3
101.6	3,820	4,297	5,252	6,207	7,162	9,072	11,940	13,560	15,278	16,235	4
127.0	3,056	3,438	4,202	4,966	5,730	7,258	9,550	10,850	12,224	12,985	5
152.4	2,546	2,865	3,501	4,138	4,775	6,048	7,960	9,040	10,186	10,820	6
177.8	2,183	2,455	3,001	3,547	4,092	5,183	6,820	7.750	8,732	9,275	7
203.2	1,910	2,148	2,626	3,103	3,580	4,535	5,970	6,780	7,640	8,115	8
228.6	1,698	1,910	2,334	2,758	3,182	4,032	5,305	6,030	6,792	7,215	9
254.0	1,528	1,719	2,101	2,483	2,865	3,629	4,775	5,425	6,112	6,495	10
304.8	1,273	1,432	1,751	2,069	2,386	3,023	3,980	4,520	5,092	5,410	12
355.6	1,091	1,228	1,500	1,773	2,046	2,592	3,410	3,875	4,366	4,640	14
406.4	955	1,074	1,313	1,552	1,791	2,268	2,985	3,390	3,820	4,060	16
457.2	849	955	1,167	1,379	1,591	2,016	2,655	3,015	3,396	3,605	18
508.0	764	859	1,050	1,241	1,432	1,814	2,390	2,715	3,056	3,245	20

Credit: Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987, pg. 607.

INTERPRET GRINDING WHEEL MARKINGS

Use Handout 1.1 to interpret and record the following grinding wheel markings. (Answer to the right of each term.)

32A36-I8VBE

1. Abrasive -
2. Grain/grit size -
3. Grade -
4. Structure (number) -
5. Bond type -

39C60-J6VK

6. Abrasive -
7. Grain/grit size -
8. Grade -
9. Structure -
10. Bond type -

NZ46-H8V40

11. Abrasive -
12. Grain/grit size -
13. Grade -
14. Structure -
15. Bond type -

ANSWERS TO ASSIGNMENT SHEET 1.1

1. 32 alum. oxide
2. medium
3. medium
4. 8
5. vitrified
6. 39 silicon carbide
7. medium
8. medium
9. 6
10. vitrified
11. NZ Alundum (alum. oxide)
12. medium
13. soft
14. 8
15. vitrified

INSPECT GRINDING WHEEL

Equipment:

Type #1 straight grinding wheel
Non-metallic instrument

Procedure:	Evaluation 3	2	1	N
1. Carefully handle wheel. Place finger through bore and balance wheel.	—	—	—	—
2. Tap wheel edge with non-metallic instrument.	—	—	—	—
3. Report finding to supervisor.	—	—	—	—
4. Carefully store wheel and replace non-metallic instrument.	—	—	—	—
Average of above evaluations*	—	—	—	—

*This average is the student's final evaluation for competency K4: Inspect grinding wheel.

SELECT AND MOUNT GRINDING WHEEL
(Large-diameter hole)

Equipment:

Bench
Arbor
Two blotters
Flange
Six cap screws
Allen wrench
Cloth

Procedure:	Evaluation 3	2	1	N
1. Clean bench and place arbor on this surface.	—	—	—	—
2. Slide wheel onto arbor. (Bore of wheel should be about .005 inch bigger than diameter of arbor.)	—	—	—	—
NOTE: Blotter must be placed on both sides of arbor.				
3. Place flange on arbor. Line up cap screw holes in flange with mating holes on arbor.	—	—	—	—
4. Place cap screws in flange and screw them all finger-tight.	—	—	—	—
5. Tighten one screw and then the diametrically opposite one to give uniform pressure. Repeat until all screws are tight.	—	—	—	—
6. Check, starting at cap screw #1, and repeat tightening as before. Corners of wheel seatings must be undercut.	—	—	—	—
7. Ask instructor to inspect your work.	—	—	—	—
8. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.	—	—	—	—
Average of above evaluations*	—	—	—	—

*This average is the student's final evaluation for competency K6: Select and mount grinding wheel.

BALANCE GRINDING WHEEL USING A MANDREL

INSTRUCTOR'S NOTE: It is assumed that the student will true the wheel before removing it from the machine. Existing weight must first be removed by instructor.

Equipment:

Chalk	Collet extractor
Machine	Balancing unit
Dresser	Mandrel
	Cloth

Procedure:	Evaluation 3	2	1	N
1. Start wheel head and allow to run until machine attains normal working temperature. Turn on coolant.	—	—	—	—
2. Apply small infeeds of diamond until wheel is trued.	—	—	—	—
3. Turn off coolant and allow wheel to run for approximately one minute.	—	—	—	—
4. Stop machine. Remove wheel guard and locknut.	—	—	—	—
5. Screw on collet extractor. Remove complete wheel unit.	—	—	—	—
NOTE: Use both hands when removing wheel; take care not to hit wheel on any machine part.				
6. Prepare balancing unit on flat, clean surface. Lower protective guards.	—	—	—	—
7. Place leveling plate on balancing ways. Adjust unit until bubble in leveling plate is concentric with circle engraved on the glass.	—	—	—	—
NOTE: This is a precision unit; use it with care.				
8. Clean bore of wheel flange unit.	—	—	—	—
9. Mount unit on mandrel. Raise protective guard.	—	—	—	—
10. Place wheel to be balanced on top of protection slides and gently lower onto balancing ways.	—	—	—	—
11. Visually ensure that balancing mandrel is at right angle to balancing ways. Allow wheel to slowly revolve by its own momentum until it stops.	—	—	—	—
12. Place chalk mark at bottom to indicate heavy point. Turn wheel 90°, first to left, then to right, to check location of heavy point.	—	—	—	—
13. Replace weights at 90° to heavy point, and then diametrically opposite (i.e. across from each other).	—	—	—	—
14. Move weights equally towards light side approximately .125 at a time until assembly remains static in any position.	—	—	—	—

15. Remount assembly on wheel head, replace guard and redress wheel before putting into operation. — — — —

16. Replace all tools and equipment properly to the correct location. — — — —

Average of above evaluations* — — — —

*This average is the student's final evaluation for competencies I34 and K5.

MODULE: GRINDERS

UNIT III: SURFACE GRINDER PREPARATION AND SET-UP

LESSON 2: DRESSING AND TRUING WHEELS

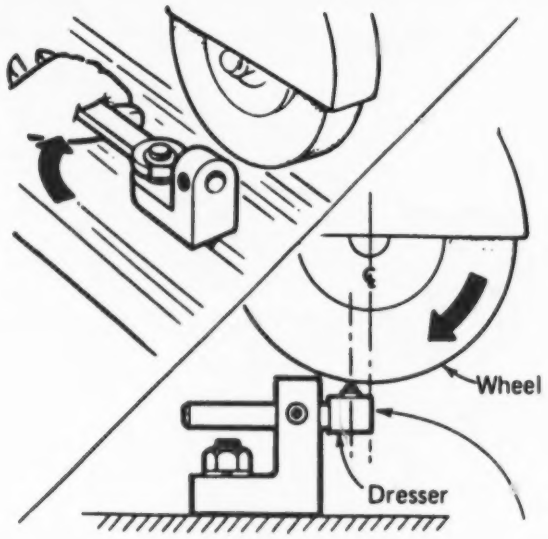
I. Dressing the face of the grinding wheel **(TM 2.1)**

A. Mount the diamond dresser.

1. Clean the table and diamond holder.

2. Mount and secure the diamond tool in holder, ensuring that a sharp edge will be presented to the grinding wheel.

3. Position the holder at the end of the magnetic chuck, switch chuck on and check that the holder is held securely. An alternate method can be used; the diamond tool can be mounted in a holder directly on the machine.



Credit: Kibbe, Richard R., et. al. Machine Tool Practices. New York: John Wiley and Sons, 1979, pg. 39. Reprinted by permission of John Wiley & Sons, Inc.

B. Set the diamond in position.

1. Position wheel head so that the bottom of wheel is higher than the diamond point on out-rotation side of wheel center line. When positioning the diamond tool, ensure that the wheel is stopped or well clear of the work area.

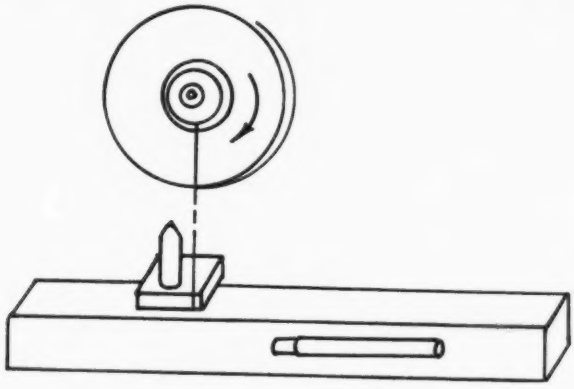
2. Use table traverse movement; position the diamond point directly below the wheel center or on the out-rotation side.

NOTE: When the diamond tool is mounted in the vertical position, a trailing angle is achieved by positioning the diamond point away from the center line of the wheel on the out-rotation side.

3. Switch on wheel head motor. Allow the wheel head bearing to reach normal working temperature before commencing (approximately 1-2 minutes).

CAUTION: Ensure that the wheel guard is in position. Stand to one side of the machine when starting the motor.

4. Apply downward feed to the grinding head, bringing wheel into light contact with diamond. Control the wheel approach by sighting the gap between wheel and diamond.



5. Using the table cross-feed, move the diamond clear of the wheel.

C. True or dress for rough grinding.

1. Switch on coolant pump and direct coolant to cover full face of the wheel.

2. Cross-feed wheel back and forth across diamond, applying approximately .002 inch down-feed each pass.

3. Use fast, even rate of crossfeed movement.

4. Continue downfeed and longitudinal movement until the face is fully cleaned up or all dull, abrasive grains and clogging metal have been removed.

5. When dressing has been completed, allow coolant to wash away loose particles from wheel; turn off coolant.

NOTE: When truing or dressing, remove only the minimum amount necessary from the wheel. To increase diamond life and achieve good surface finish, turn the diamond dresser frequently in the holder; this exposes new, sharp facets.

D. Dress for finish grinding.

1. Dress wheel for rough grinding.

2. Reduce wheel head downfeed to about .0005 inch at each pass.

3. Use a slow, even rate of crossfeed movement; two or three passes should be sufficient to achieve a satisfactory result.

4. At some setting after removing final cut, take two or three passes of diamond across the face of wheel with no downfeed.

E. Remove diamond.

1. Move table longitudinally to move diamond maximum distance from wheel.

2. Remove dresser.

3. Clean machine table or chuck.

II. Relieving and dressing the side of the wheel using stick and diamond

NOTE: When vertical faces have to be ground, this operation is carried out using a dished or disk wheel which has relieved sides to form a cutting area at the wheel periphery.

A. Switch on wheel head motor.

B. Dress wheel face.

C. Relieve side of wheel.

1. Move table longitudinally to clear magnetic chuck from under wheel.

CAUTION: Use extreme caution when relieving the side of wheels by hand. If available, a radius/angle dresser is safer to use.

2. Brace your arm against machine, facing half left and slightly to the right of wheel.

3. Hold dressing stick firmly in both hands. Touch stick to side of wheel (bottom right-hand quarter).

4. Applying light pressure, cross-feed stick back and forth until wheel side is relieved to sufficient depth and diameter. Leave a hand on periphery of between .030 and .060 inch.

E. Dress land.

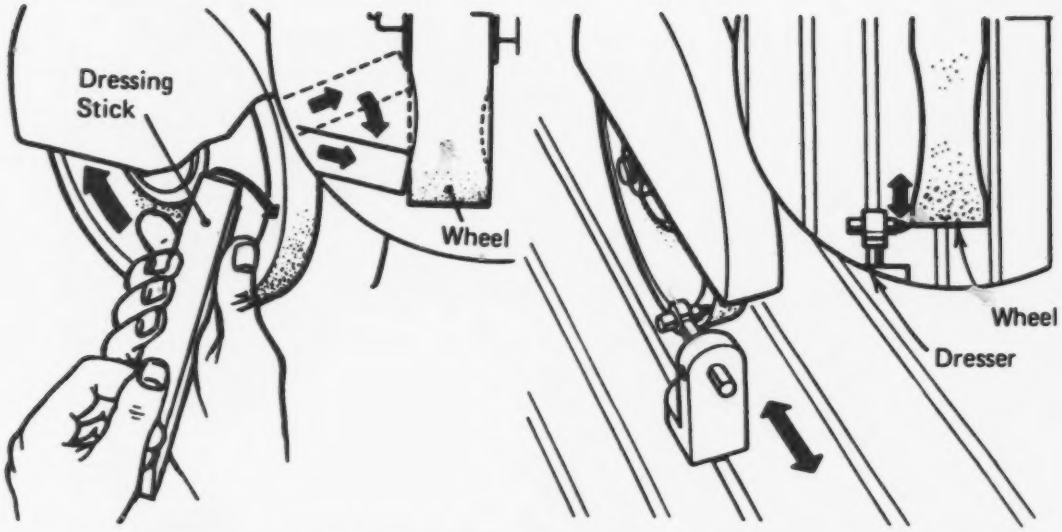
1. Mount diamond holder with diamond horizontally.

2. Using table and wheel head movements, position diamond to land. Ensure that wheel does not hit table or the diamond holder.

3. Longitudinally move diamond across land; apply approximately .002 inch cross-feed at each pass until land is fully dressed.

4. Longitudinally move diamond clear of wheel and remove holder from table.

5. Clean machine.



Credit: Kibbe, Richard R., et. al. Machine Tool Practices. New York: John Wiley and Sons, 1979, pg. 42. Reprinted by permission of John Wiley & Sons, Inc.

III. Techniques for dressing on angle

A. Dress face of wheel.

B. Position angle gage block.

1. Select block with required angle. A protractor with blade could be substituted if angle is ±1° or greater tolerance.

2. Place on chuck against back plate.

3. Place slide support block against angle gage block.

4. Clamp diamond to V-block using V-block clamp.

5. Place V-block on slide support block.

6. Switch on magnetic chuck.

C. Position diamond.

1. Position grinding wheel vertically with center to diamond point.

2. Move table to bring diamond to edge of wheel.

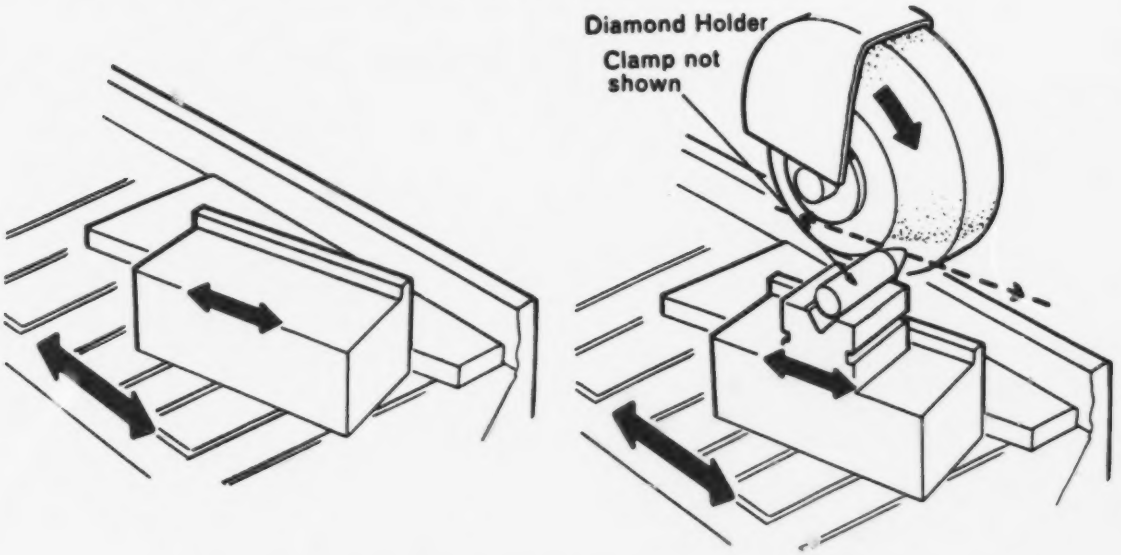
D. Dress angle.

1. Switch on wheel.

2. Slide V-block back and forth along slide support block, feeding in by use of handwheel.

3. Continue until required form is obtained. Form grinding can be classified as an operation performed on the surface grinder, as is surface and angular grinding.

4. Switch off chuck. Remove blocks and clean chuck.



Credit: Kibbe, Richard R., et. al. Machine Tool Practices. New York: John Wiley and Sons, 1979, pg. 43. Reprinted by permission of John Wiley & Sons, Inc.

TRUING, DRESSING AND BALANCING

Use these clues to diagnose grinding problems.

- An out-of-round wheel can cause chatter marks.

- Improper dressing can cause the wheel to "load" or act too soft.

- Infrequent dressing can also cause wheel loading.

- A scratched workpiece can be corrected by dressing the wheel to eliminate coarse grading or foreign matter.

- Diamond-shaped lines on a workpiece can be corrected by dressing the wheel face slowly.

- Chatter marks can result from an out-of-balance wheel, as well as an out-of-round wheel.

DRESS AND TRUE GRINDING WHEEL

INSTRUCTOR'S NOTE: For this evaluation, either an automatic or manual feed surface grinder can be used; using a worn type I wheel will cut costs.

Equipment:

Diamond holder
Type I wheel
Cloth

Procedure:	Evaluation 3	2	1	N
1. Mount diamond dresser. Set diamond in position.	—	—	—	—
2. Switch on magnetic chuck. Switch on wheel head motor and coolant.	—	—	—	—
3. Control the wheel approach.	—	—	—	—
4. Using the table longitudinal movement, move the diamond back and forth across face of wheel applying approximately .002 inch downfeed.	—	—	—	—
5. Continue until face is fully cleaned up.	—	—	—	—
6. Allow coolant to wash particles from wheel and then turn off coolant.	—	—	—	—
7. Remove diamond and clean machine table or chuck.	—	—	—	—
8. Replace all tools and equipment to proper location and clean machine.	—	—	—	—
Average of above evaluations*	—	—	—	—

*This average is the student's final evaluation for competency K7: Dress and true machine tool grinding wheel.

MODULE: GRINDERS

UNIT III: SURFACE GRINDER PREPARATION AND SET-UP

UNIT TEST

Match the following definitions and terms.

____ 1.	Material that holds abrasive together; designated as a letter or letters and/or numbers	a. Abrasive
____ 2.	Rate at which the wheel is fed into workpiece each time the table reverses	b. Arbor
____ 3.	Grinding wheel material that acts as the cutting agent	c. Bond
____ 4.	Finishing process that uses loose abrasive grains to produce desired surface finish	d. Dressing
____ 5.	Main shaft on which the wheel is held	e. Face
____ 6.	Surface feet per minute	ab. Finish grinding
____ 7.	Grinding operation used to improve dimensional accuracy and obtain desired finish	ac. Grade
____ 8.	Method of preparing the grinding wheel by exposing new, sharp cutting grains; also maintains wheel form	ad. Grain or grit
____ 9.	Grain spacing; designated by open or closed	ae. Lapping
____ 10.	The surface of the grinding wheel at the outermost diameter	bc. Periphery
____ 11.	Grinding wheel revolutions per minute	bd. sfpm
____ 12.	Operation used on all newly mounted wheels to ensure that cutting face of grinding wheel runs concentric to the spindle axis	be. Structure
____ 13.	Strength of the bond that holds wheel abrasives together	cd. Truing
____ 14.	Outermost dimension of the grinding wheel	ce. Work feed
____ 15.	Size of abrasive; expressed as a number	de. Wheel speed (rpm)

Match the letter on the types of grinding wheels with the correct term/application.

___ 16. Type #1/surface, internal, cylindrical and offset grinding

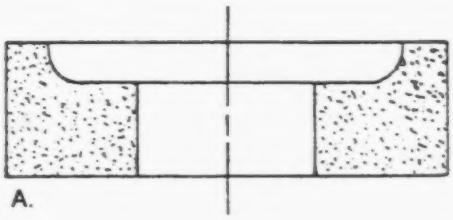
___ 17. Type #5/surface, cylindrical and off-hand grinding

___ 18. Type #7/surface and cylindrical grinding

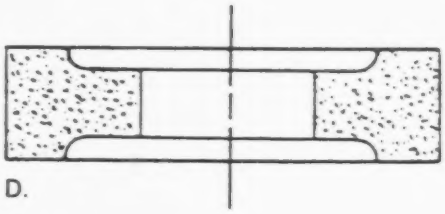
___ 19. Type #6/cutter grinding; vertical spindle grinding

___ 20. Type #11/tool cutter grinding

___ 21. Type #12/tool room; tool cutter applications



A.



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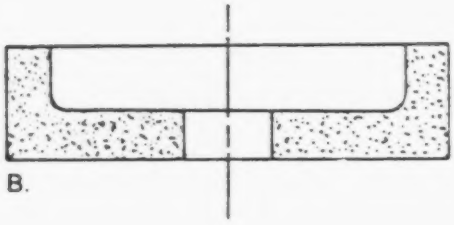

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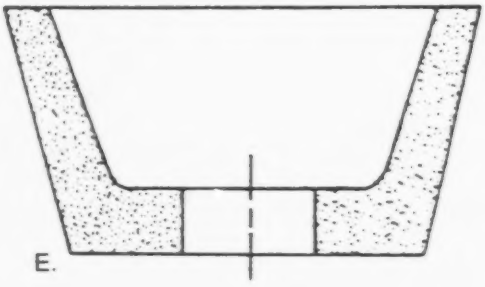

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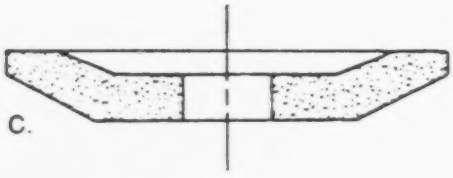
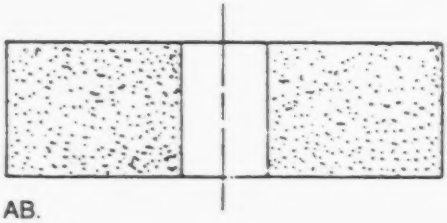


C.



AB.

Each set-up technique and consideration below is followed by five suggested answers or completions. Select the one which is best in each case.

___ 22. What is the grade of a grinding wheel?

a. Degree of strength with which the abrasive is held by the bond
b. Quality of the abrasive
c. Hardness of the abrasive
d. Cutting life of the abrasive
e. All of the above

___ 23. What is the density of a grinding wheel?

a. Type bond
b. Grain size
c. Structure
d. Shape
e. None of the above

___ 24. How is a grinding wheel's grade defined?

a. Numbers 1 to 15
b. Letters a to z
c. Fine, medium and coarse
d. Two numbers and a letter
e. None of the above

___ 25. What is the maximum cross-feed for surface grinding?

a. .025
b. 1/4 wheel width
c. 1/2 wheel width
d. 3/4 wheel width
e. None of the above

___ 26. Which method is <u>not</u> recommended when inspecting a new grinding wheel?

a. Mounting test
b. Check arbor size
c. Visual test
d. Ring test
e. None of the above

___ 27. Which combination is best for roughing out the workpiece when grinding?

a. Low work speed, heavy infeed, fast longitudinal movement
b. Off-hand grinding technique
c. High work speed, light infeed, low longitudinal movement
d. Lapping compound
e. All of the above

___ 28. What is used to dissipate heat with fragile work?

a. No coolant to balance conditions
b. High work speed, light infeed
c. Low work speed, heavy infeed
d. Vacuum system
e. None of the above

___ 29. If wheel acts hard and glazes, what action should be taken?

a. Smaller wheel diameter
b. Larger wheel diameter
c. Higher work speed and longitudinal speed
d. Lower work speed and longitudinal speed
e. None of the above

___ 30. Which is <u>not</u> a method used to improve surface finish?

a. Selecting proper size of grit
b. Truing and dressing
c. Fine grit wheel
d. Coarse grit wheel
e. None of the above

Refer to this grinding wheel marking for questions 31-34: **32A 46-H8VBE**.

___ 31. In the marking above, what is '32A'?

a. Grade
b. Manufacturer's symbol
c. Abrasive
d. Bond
e. None of the above

___ 32. In the marking above, what does '46' refer to?

a. Grit size
b. Abrasive
c. Bond type
d. Structure
e. None of the above

___ 33. What does 'H' refer to?

a. Structure
b. Grade
c. Abrasive
d. Bond type
e. None of the above

___ 34. In the previous marking, what does 'V' indicate?

a. Bond
b. Grade
c. Abrasive
d. Structure
e. None of the above

___ 35. When grinding high-speed steel tools, what kind of grinding wheel should be used?

a. Coarse and soft grit
b. Medium and soft grit
c. Coarse and hard grit
d. Fine and hard grit
e. None of the above

___ 36. Grinders with aluminum oxide wheels are not appropriate for which of the following?

a. High speed tools
b. Iron or steel
c. Aluminum or brass
d. Punches and chisels
e. All of the above

___ 37. Which operation(s) can not be performed on the surface grinder?

a. Surface
b. Angular
c. Form
d. Internal
e. All the above

___ 38. Which describes a loaded grinding wheel?

a. Bits of work embedded on the wheel
b. A smoothly worn face
c. Soaked with coolant
d. Weights added for balance
e. All of the above

___ 39. How is a sharp cutting edge kept on a diamond dresser?

a. Chipping
b. Dressing with a special wheel
c. Rotating the holder
d. Sharpening on a bench grinder
e. None of the above

___ 40. What can the operator do to correct a loaded condition?

a. Dress the wheel
b. True the wheel
c. Remove the loaded portion from the wheel
d. Use a diamond dresser
e. All of the above

___ 41. When positioning the diamond tool, what should the wheel be kept clear of?

a. Magnetic chuck
b. Hydraulic pump
c. Chipping stone
d. Work area
e. All of the above

___ 42. How should one control the wheel approach between the wheel and diamond?

a. Sight the gap visually
b. Place paper on diamond
c. Set graduated downfeed dial
d. Turn hydraulic drive on automatic
e. All of the above

___ 43. What is done first when starting the wheel-head motor?

a. Face the end of work table
b. Lower the wheel onto work surface
c. Remove the magnetic chuck
d. Stand to one side
e. None of the above

___ 44. How much downfeed is applied to the wheel head when rough truing and dressing?

a. .0002"
b. .005"
c. .002"
d. .020"
e. None of the above

___ 45. How much downfeed is applied to the wheel head when finish truing and dressing?

a. .00005
b. .0005
c. .005
d. .050
e. None of the above

___ 46. How much downfeed is used on final passes after removing the final dressing finish/truing cut?

a. No downfeed
b. One-third downfeed
c. Triple downfeed
d. Double downfeed
e. None of the above

___ 47. When relieving the side of a grinding wheel, how much land should be left on the periphery of the wheel edge?

a. .015 to .020 inch
b. .030 to .060 inch
c. .080 to .120 inch
d. .125 to .375 inch
e. None of the above

___ 48. When dressing an angle on a grinding wheel, how should the angle gage block be positioned?

a. Against the motor head
b. Upon the wheel guard
c. Lying on the magnetic base
d. Standing on the magnetic base
e. None of the above

ANSWERS TO UNIT TEST

1.	c	(K4)
2.	ce	(K4)
3.	a	(K4)
4.	ae	(K4)
5.	b	(K4)
6.	bd	(K4)
7.	ab	(K4)
8.	d	(K4)
9.	be	(K4)
10.	e	(K4)
11.	de	(K4)
12.	cd	(K4)
13.	ac	(K4)
14.	bc	(K4)
15.	ad	(K4)
16.	ab	(K6)
17.	a	(K6)
18.	d	(K6)
19.	b	(K6)
20.	e	(K6)
21.	c	(K6)
22.	a	(K6)
23.	c	(K6)
24.	b	(K6)
25.	c	(K6)
26.	a	(K6)
27.	a	(K6)
28.	b	(K6)
29.	c	(K6)
30.	d	(K6)
31.	c	(K6)
32.	c	(K6)
33.	b	(K6)
34.	a	(K6)
35.	b	(K6)
36.	c	(K6)
37.	e	(K9)
38.	a	(K7)
39.	c	(K7)
40.	e	(K7)
41.	d	(K7)
42.	c	(K7)
43.	d	(K7)
44.	c	(K7)
45.	b	(K7)
46.	a	(K7)
47.	b	(K7)
48.	c	(K7)

MODULE: GRINDERS

UNIT IV: SURFACE GRINDING FLAT AND ANGULAR SURFACES

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to determine how to hold a workpiece for grinding flat and angular workpieces. The student should also be able to set up, grind and inspect flat and angular workpieces on the surface grinder. This knowledge will be evidenced through demonstrations and by achieving specified scores on the unit test.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Match terms with definitions or illustrations.

1.2 Describe proper workpiece and work-holding mounting procedures.

1.3 Identify proper methods to grind flat and angular workpieces.

1.4 Grind workpiece on magnetic chuck using power feed. (competency K8, JS 1.1)

1.5 Grind workpiece square on surface grinder. (competency K9, JS 1.2)

1.6 Indicate workpiece to be ground. (competency K10, JS 1.2)

1.7 Grind angular surfaces. (competency K11, JS 1.3)

MODULE: GRINDERS

UNIT IV: SURFACE GRINDING FLAT AND ANGULAR SURFACES

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: SURFACE GRINDING FLAT AND ANGULAR SURFACES

   a. Information outline

   b. Transparencies

      TM 1.1: Angle plate set-up
      TM 1.2: Sine bar and angle plate set-up

   c. Assignment sheets

      AS 1.1: Grinding a set of set-up blocks
      AS 1.2: Grinding a V-block

   d. Answers to assignment sheets

   e. Job sheets

      JS 1.1: Grind workpiece on magnetic chuck using power feed
      JS 1.2: Grind workpiece square on surface grinder
      JS 1.3: Grind angular surfaces

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Kibbe, Richard R. Grinding Machine Operations. New York: John Wiley and Sons, 1985.

2. Krar, S. F. and J. W. Oswald. Grinding Technology. Albany, NY: Delmar Publishers, Inc., 1984.

3. Krar, S. F., J. W. Oswald and J. E. St. Amand. Technology of Machine Tools. 3rd ed. Toronto: McGraw-Hill, 1984.

4. Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987.

B. Curriculum guides

1. Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983.

2. Machinist. Frankfort, KY: Vocational-Technical Education Consortium of States, 1982.

3. Yettaw, Jerome. Vocational Machine Shop. University of Missouri-Columbia: Instructional Materials Laboratory, 1977.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Instructors can use this unit's assignment sheets in several ways.

   a. As a student guide to procedures being worked through in class by the instructor

   b. As a student guide when performing a practice procedure

   c. As an evaluation instrument to determine if students have mastered steps of procedure

2. Demonstrate the following methods.

   a. Preparing the magnetic chuck and workpiece

   b. Mounting and indicating workpieces

   c. Grinding flat and angular workpieces

B. Suggested supplemental materials

1. Operation and Maintenance Manual of the 618 and 818 Micromaster Series II Surface Grinding Machines. North Kingstown, RI: Brown and Sharpe Co., 1980.

2. Oberg, Erik; Franklin D. Jones; Holbrook L. Horton. Machinery's Handbook. 23rd ed. New York: Industrial Press, Inc., 1988.

3. Grinding Flat Surfaces and Squaring Stock on a Surface Grinder (MS-84-371) (video). Sedalia, MO: State Fair Community College, 1984. (Available for purchase from SFCC; available for loan from Missouri Vocational Resource Center, phone 800/392-7217 or 314/882-9610)

MODULE: GRINDERS

UNIT IV: SURFACE GRINDING FLAT AND ANGULAR SURFACES

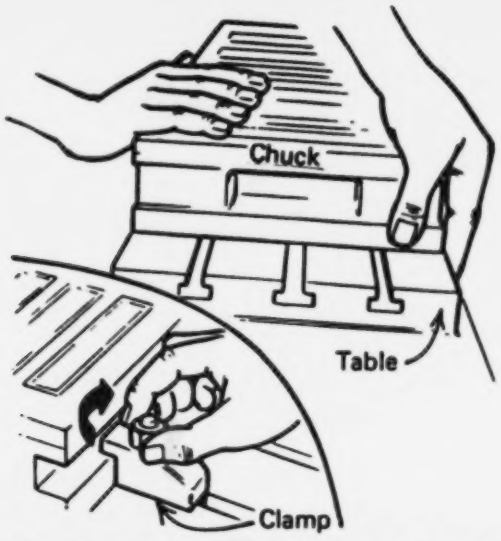
LESSON 1: SURFACE GRINDING FLAT AND ANGULAR SURFACES

I. Terms and definitions

- A. Cross--movement of grinding wheel from back to front during grinding operation
- B. Energize--to apply power to magnetic device
- C. Flat--surface that is straight and free of warps or bows
- D. Reciprocating--moving alternately back and forth
- E. Scale--carbon or other impurities on the surface of steel that has been heat-treated or hot-rolled
- F. Stone the chuck--to remove burrs by rubbing surface of magnetic chuck with hard oilstone
- G. Stress--internal strain in workpiece produced by manufacturing, machining or heat treatment
- H. Surface finish--appearance or degree of workpiece's smoothness

II. Work-holding and setting for surface grinders

- A. Setting the magnetic chuck
  1. Clean machine table; remove burrs with abrasive stone.
  2. Clean magnetic chuck; remove burrs with abrasive stone.
  3. Position magnetic chuck.
     - a. Center chuck on machine table with back plate at rear.
     - b. Remove back plate and clean rear face of chuck.
     - c. To align chuck, check that back edge of chuck is even with rear of machine table.
     - d. Position bolts and clamps, then finger-tighten nuts.



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4. Align chuck parallel to table movement.

   a. Position dial test indicator on wheel head with stylus engaged on back face of chuck.

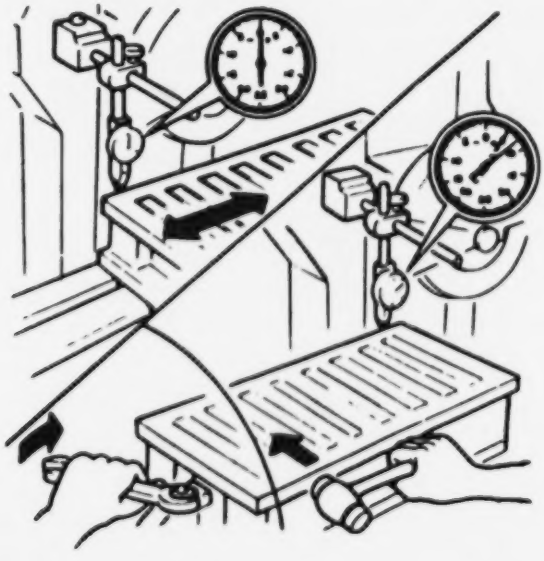
   b. Move table back and forth longitudinally, allowing stylus to cover full length of chuck.

   c. Note amount of error registered on dial indicator.

   d. Tap chuck away from dial test indicator at high reading. Use a soft hammer when tapping the magnetic chuck to prevent damage.

   e. Continue longitudinal movement and chuck position adjustment until no error is shown on dial test indicator.

   f. Tighten nuts and check reading. If no error is shown, remove dial test indicator and re-position back plate.



B. Mounting work on the magnetic chuck

1. Prepare magnetic chuck.

   a. Clean surface of chuck and check for burrs.

   b. Remove burrs by rubbing lightly with a fine stone.

2. Prepare workpiece.

   a. Examine workpiece and remove burrs.

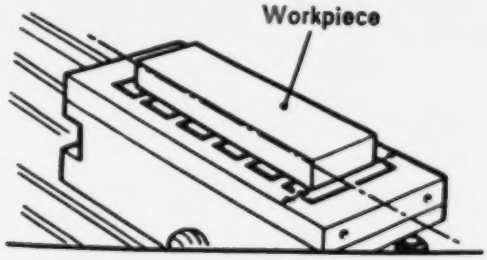
   b. Remove loose scale or particles from surface to be located on magnetic chuck.

3. Set workpiece on magnetic chuck.

   a. Center workpiece on magnetic chuck.

   b. Visually check that workpiece is over steel sections of magnet.

   c. Engage magnet and check location by attempting to move workpiece. (If any movement is felt, remove workpiece, check mating surfaces and relocate.)



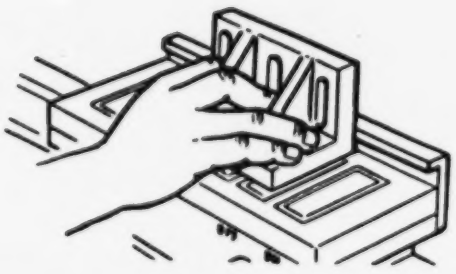
CAUTION: To hold properly, ensure that workpiece is located over three or more steel sections of the chuck.

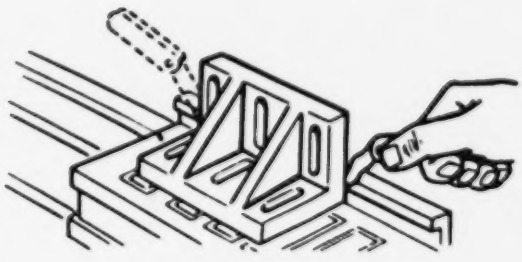
C. Mounting an angle plate on magnetic chuck **(TM 1.1)**

1. Ensure that back plate on magnetic chuck is raised and secure.

2. Slide end or rear of angle plate flush to back plate and check with feeler gages (±.001).

3. Magnetize chuck. (If unsure of the back plate accuracy, use dial indicator to check alignment of the angle plate's face.)





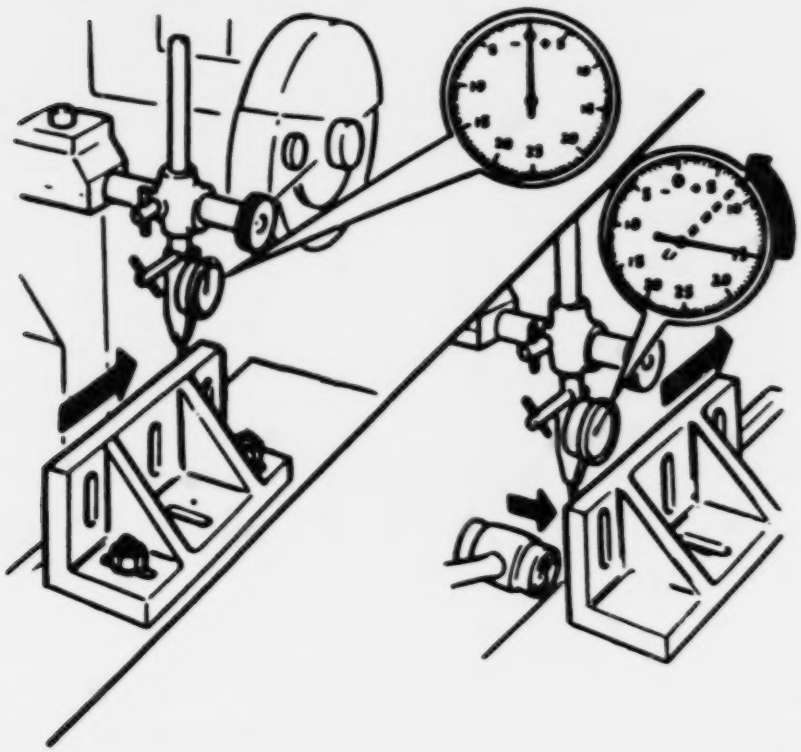
a. Place dial indicator on the wheel head column using magnetic base stand.

b. Engage stylus onto angle plate face.

c. Using longitudinal handwheel for parallel setting or cross-feed handwheel for square setting, move table back and forth, covering length of face with stylus.

d. Note the high reading, then tap end with high reading away from dial test indicator until no error is registered.

e. Remove and store indicator.



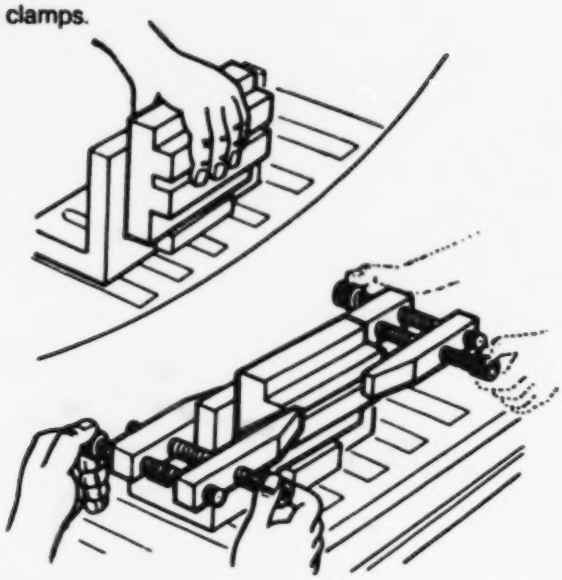
D. Clamping workpiece to angle plate

1. Position workpiece on angle plate and hold in position. (To gain height to clear top of angle plate, parallels may be used.)

2. Position clamps and lightly tighten.

3. Check workpiece setting. Adjust if necessary.

4. Tighten clamps.

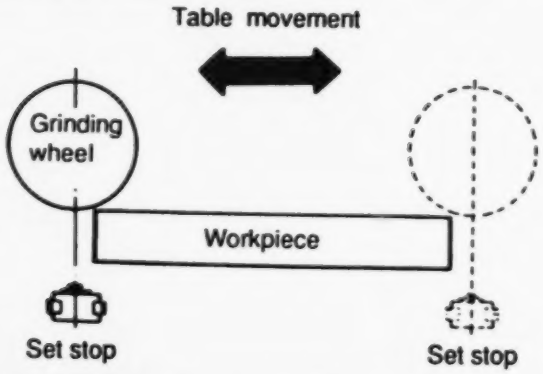


E. Setting the table longitudinal movement stops

1. Position and set longitudinal stops.

   a. Raise wheel clear of workpiece.

   b. Longitudinally move table to position one end of the workpiece just clear of vertical centerline of wheel.



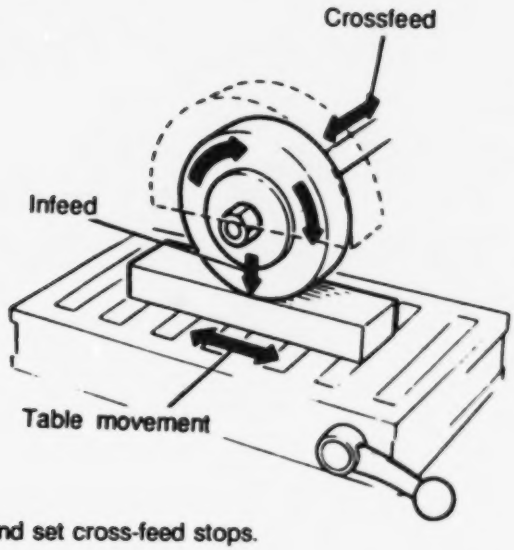
   c. Push stop up to direction change lever and lock in position.

   d. Longitudinally move table to position opposite end of workpiece and just clear of wheel.

   e. Push stop up to direction change level and lock in position.

   f. Start longitudinal movement (if available) and visually check the amount of overrun between each end of workpiece and wheel.

   g. Stop movement and adjust stops until overrun is approximately .250 to .500 inch at each end of workpiece.



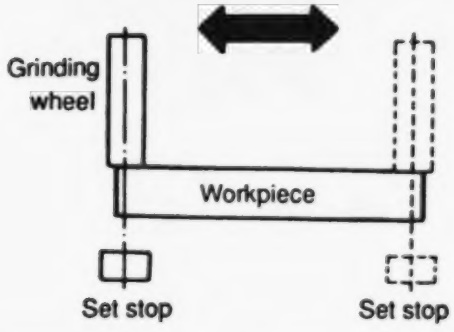
2. Position and set cross-feed stops.

NOTE: Cross-feed stops are seldom used because the direction of longitudinal movement can quickly and easily be changed by hand.

a. Raise wheel clear of workpiece.

b. Hand move cross-feed handle until approximately one-third of wheel thickness is over edge of workpiece.

c. Push stop to longitudinal trip lever and lock in position.



d. Hand move table to position one-third of wheel thickness over opposite edge of workpiece.

e. Push stop to longitudinal trip lever and lock in position.

f. Start longitudinal movement (if available) and check coverage of wheel over workpiece.

g. Adjust stops if necessary.

III. Grinding flat and angular surfaces

A. Grinding a flat face

1. Measure workpiece.

   a. Check flatness of workpiece.

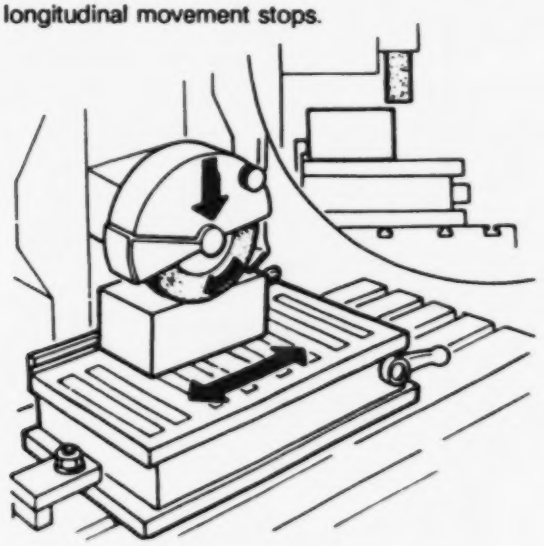
   b. Check parallelism; using micrometer, note high positions.

2. Dress wheel.

NOTE: The surface area of the face to be ground, the amount of material to be removed and surface finish requirements are factors to be considered in deciding whether the operation can be successfully carried out with single dressing of the wheel or if a roughing out and finish grinding technique is necessary.

3. Remove all burrs, clean chuck and mount workpiece.

4. Set table longitudinal movement stops.



5. Touch off wheel to workpiece.

   a. Visually align wheel over highest point.

   b. Hand feed wheel head down, watching gap until approximately .010 inch remains between wheel and workpiece.

   c. Engage longitudinal movement.

   d. Hand feed wheel down, using fine feed until sparks and/or sound indicate that wheel is touching top of workpiece.

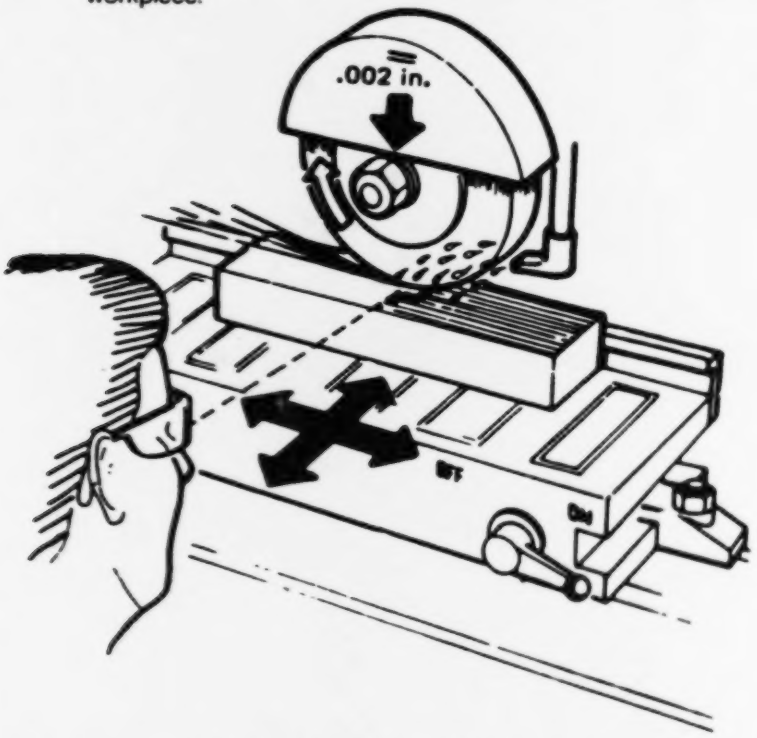
   e. Cross-feed workpiece clear of the wheel.

6. Clean up face; rough out.

   a. Start coolant pump and direct coolant stream between wheel and workpiece.

b. Apply .002 inch downfeed to wheel head; using hand cross-feed, position side of workpiece in line with front side of wheel.

c. Using hand or automatic cross-feed, allow wheel to pass over whole face of workpiece.



d. Stop cross-feed, apply additional downfeed and reverse cross-feed.

e. Continue applying downfeed and longitudinal movement until face has cleaned up fully.

f. Stop all movement, position workpiece maximum distance from wheel and turn off coolant.

g. Remove workpiece from chuck.

7. Dress wheel for finish grinding.

8. Reset workpiece on chuck.

9. Finish grind workpiece.

a. Ensure that wheel is clear and engage longitudinal table movement.

b. Using cross-feed, position edge of workpiece under wheel.

c. Carefully feed wheel head down until wheel makes light contact with workpiece.

d. Cross-feed workpiece clear of wheel.

e. Apply .0005 inch cut.

f. Engage cross-feed, turn on coolant and grind face.

g. Continue applying downfeed and longitudinal movement until face is fully ground.

h. Allow wheel to spark out. Using no downfeed, the wheel has completed its cut and no more sparks are visible.

i. Stop all movement, position workpiece maximum distance from wheel and turn off coolant.

j. Remove workpiece from chuck.

10. Measure workpiece; check flatness and surface finish.

11. Remove sharp edges using fine, abrasive stone.

12. Demagnetize workpiece.

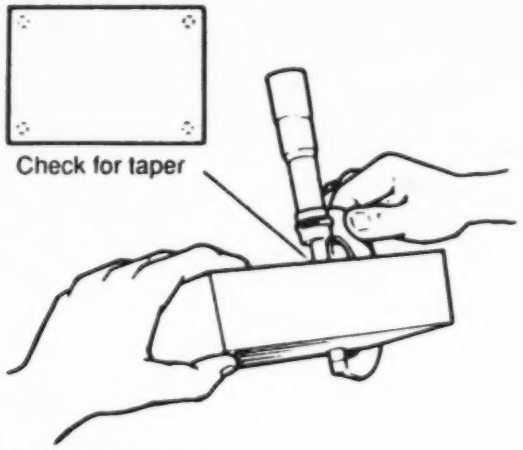
B. Grinding opposite sides flat and parallel

NOTE: In mounting the workpiece directly onto the magnetic chuck, the parallelism accuracy depends on the condition of the chuck and workpiece surfaces.

1. Measure workpiece.

a. Determine allowance for grinding.

b. Check parallelism; note high position.



2. Dress wheel for roughing out.

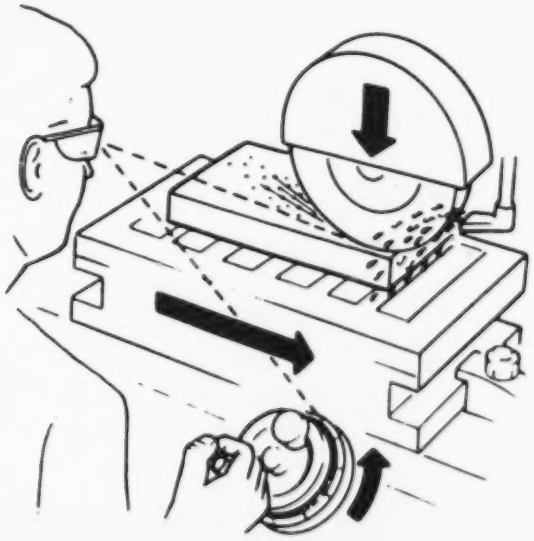
3. Mount workpiece on magnetic chuck.

4. Set table longitudinal stops.

5. Clean up face (remove minimum material).

6. Remove workpiece from chuck (move workpiece maximum distance from wheel).

7. Measure workpiece.
    a. Clean workpiece and deburr.
    b. Determine remaining allowance for grinding.
    c. Check parallelism.
8. Mount workpiece.
9. Rough grind workpiece to within .002 inch of finish size.
10. Remove workpiece from chuck.
11. Dress wheel for finish grinding.
12. Measure workpiece.
    a. Determine remaining grinding allowance (for final size requirement).
    b. Check parallelism.
13. Mount workpiece.
    a. Ensure that chuck and workpiece surfaces are clean.
    b. Energize chuck.
14. Finish grind workpiece to size.
    a. Ensure that wheel is clear of workpiece and engage longitudinal table travel.
    b. Using cross-feed, position edge of the workpiece under wheel.
    c. Carefully apply .0005 inch downfeed, engage cross-feed and turn on coolant.
    d. Allow wheel to pass over entire surface of workpiece; stop cross-feed.
    e. Working to wheel head index, continue applying downfeed and longitudinal movement until remaining grinding allowance has been removed.



f. After final downfeed has been applied, allow wheel to pass over face once or twice to spark out.

g. Stop all movement, clear workpiece from wheel and turn off coolant.

h. Remove workpiece from chuck.

15. Remove sharp edges using fine, abrasive stone.

16. Measure workpiece. Check thickness, flatness, parallelism and surface finish.

17. Demagnetize workpiece.

C. Grinding an angular face using sine bar and angle plate

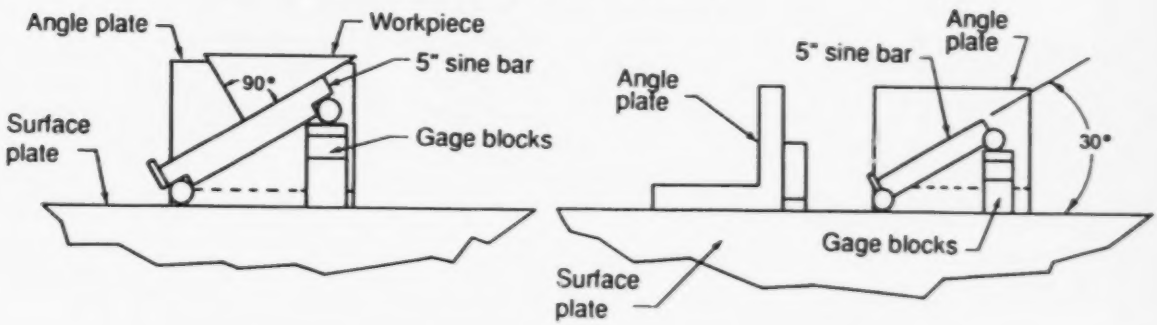
NOTE: The method selected for holding and setting the workpiece depends on the angular accuracy required. Grinding procedure is the same as for grinding a flat face. The angle plate/sine bar method will be used.

1. Dress wheel.

a. Dress wheel face.

b. Switch off wheel head.

2. Select angle plate and indicate workpiece using sine bar.



Credit: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 189-190. Used by permission.

a. Set base of angle plate on surface plate.

b. Set sine bar against angle plate using gage blocks to raise one end.

c. Place workpiece on sine bar with long side of 90° angle on surface of sine bar and against angle plate.

d. Ensure that unground surface is approximately 1/8 inch above top of angle plate.

e. Place C-clamps on workpiece so that top surface can be ground.

f. Remove sine bar and gage blocks.

g. Place angle plate on clean, magnetic chuck and energize.

h. Switch on wheel head.

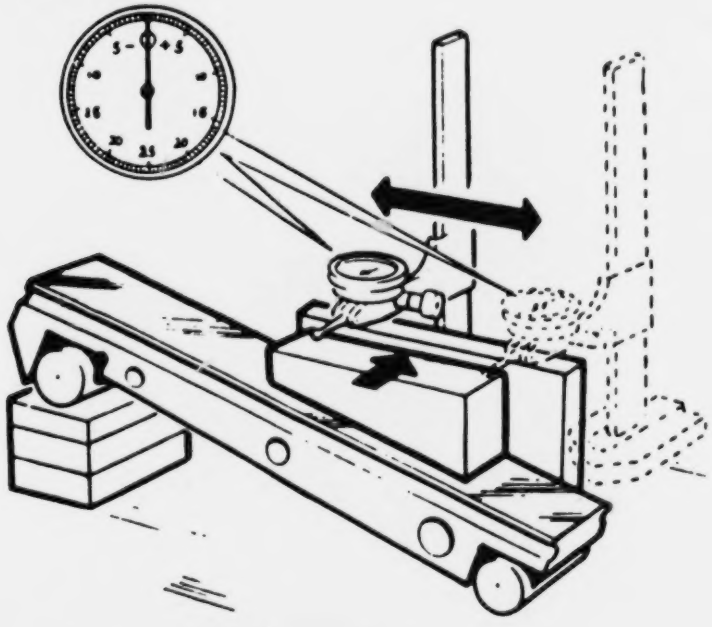
i. Adjust wheel and grind surface smooth and flat.

j. Demagnetize workpiece.

k. Remove sharp edges using fine, abrasive stone; measure workpiece.

D. Inspecting angular and flat workpieces

1. Set up sine bar.



Credit: Kibbe, Richard R. Grinding Machine Operations. New York: John Wiley and Sons, 1985, pg. 88. Reprinted by permission of John Wiley & Sons, Inc.

a. Select and clean appropriately sized sine bar.

b. Select gage blocks to build up sine bar to required angle.

c. Clean gage blocks on soft cloth.

d. Wring gage blocks together.

e. Place sine bar on surface and position gage blocks.

2. Position workpiece.

a. Deburr and clean workpiece.

b. Position workpiece angle face resting on sine bar.

c. Hold angle plate on parallel strip against side of sine bar. Slide workpiece against angle plate/parallel strip, ensuring that workpiece is flush to sine bar edge.

3. Check angular face.

   a. Position dial test indicator on surface plate with dial stylus engaged on one end of workpiece face.

   b. Set dial face at zero using fine adjustment on height gage.

   c. Slide dial test indicator to bring stylus to other end of workpiece face.

   d. Note any error; if the angle is correct, the dial stylus will read 0 for the full length of the angle face.

   NOTE: A vernier bevel protractor may be used for visual angular tolerance inspection.

E. Checking flatness

1. Prepare workpiece.

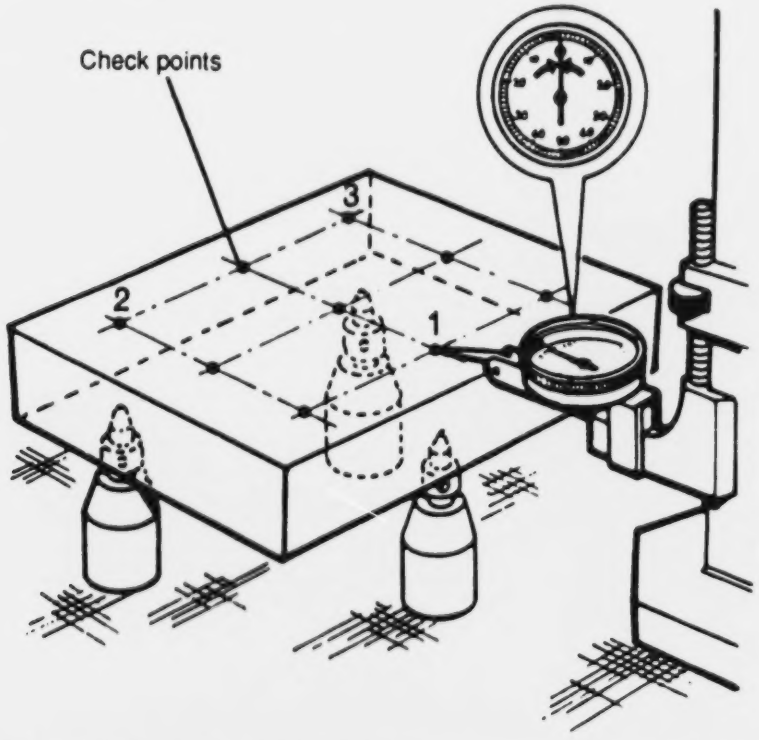
   a. Remove all burrs from workpiece and clean faces.

   b. Select three small jacks and position on surface plate to form a triangle within bounds of workpiece.

   c. Position workpiece on jacks, ground face up.

   d. Adjust height of jacks to visually align top face of workpiece parallel to surface plate.

2. Check workpiece.

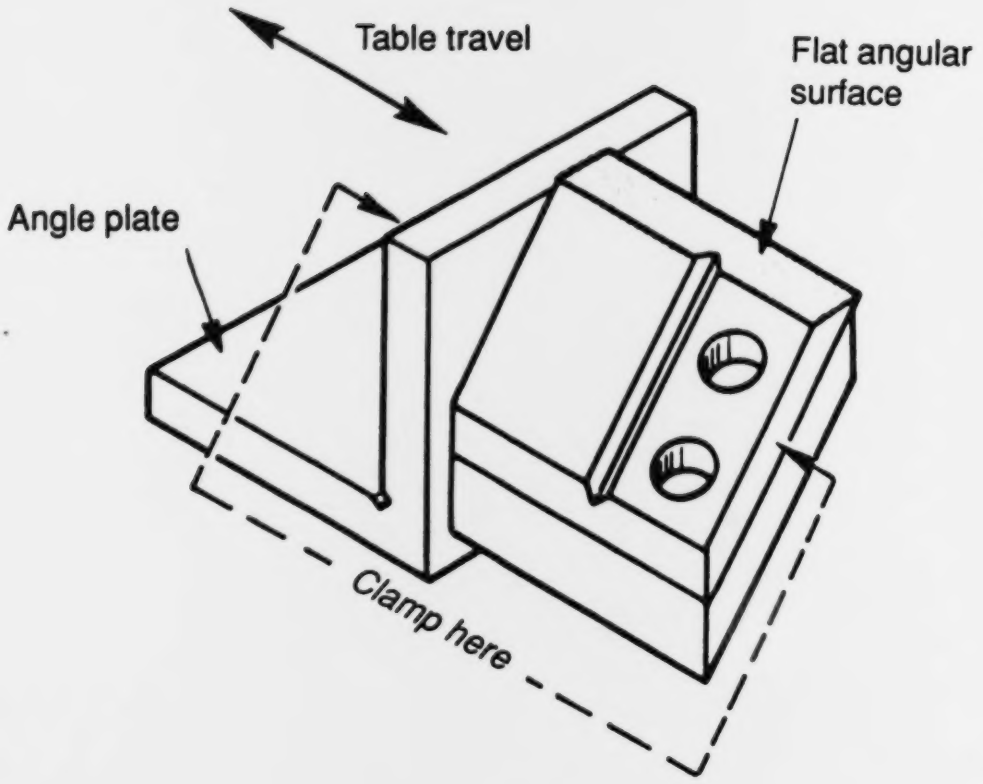


Credit: Kibbe, Richard R. Grinding Machine Operations. New York: John Wiley and Sons. 1985 pg 88 Reprinted by permission of John Wiley & Sons, Inc.

a. Set top face of workpiece parallel to surface plate by adjusting jacks to obtain a dial indicator reading of 0 in all corners of workpiece.

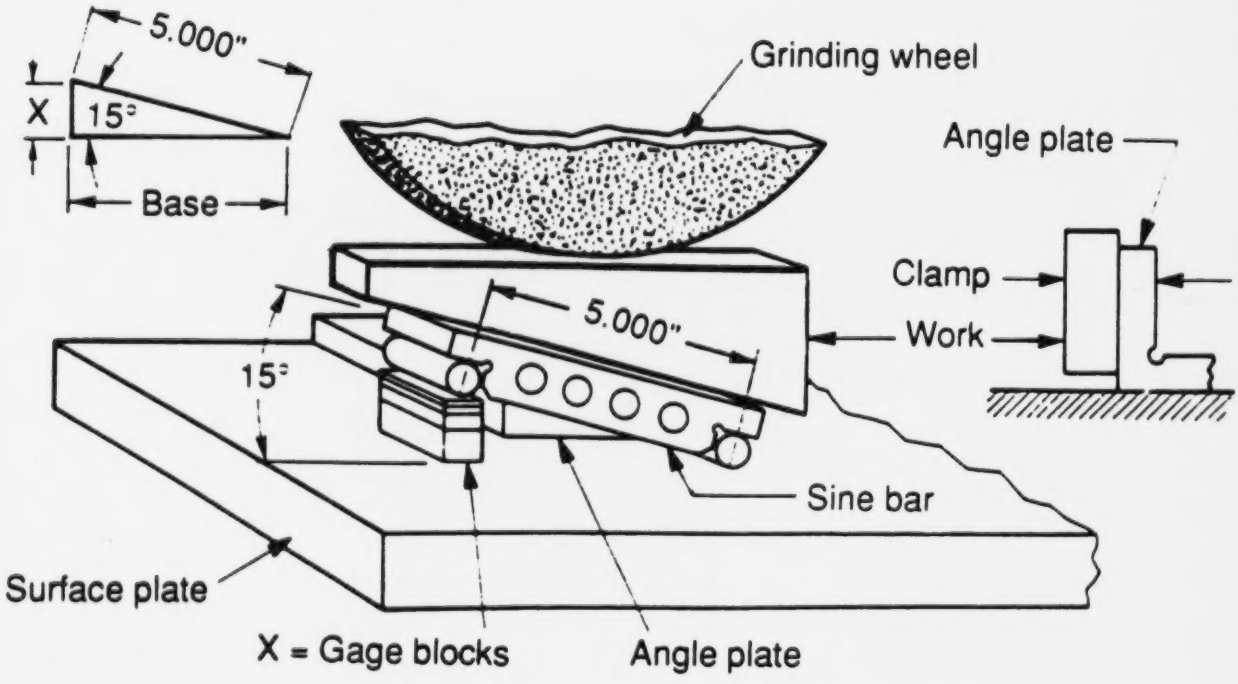
b. Check along each edge of workpiece and in the middle for flatness. Error will be indicated by the amount the dial test indicator needle moves from the 0 reading.

ANGLE PLATE SET-UP



Credit: Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987, pg. 466.

SINE BAR AND ANGLE PLATE SET-UP

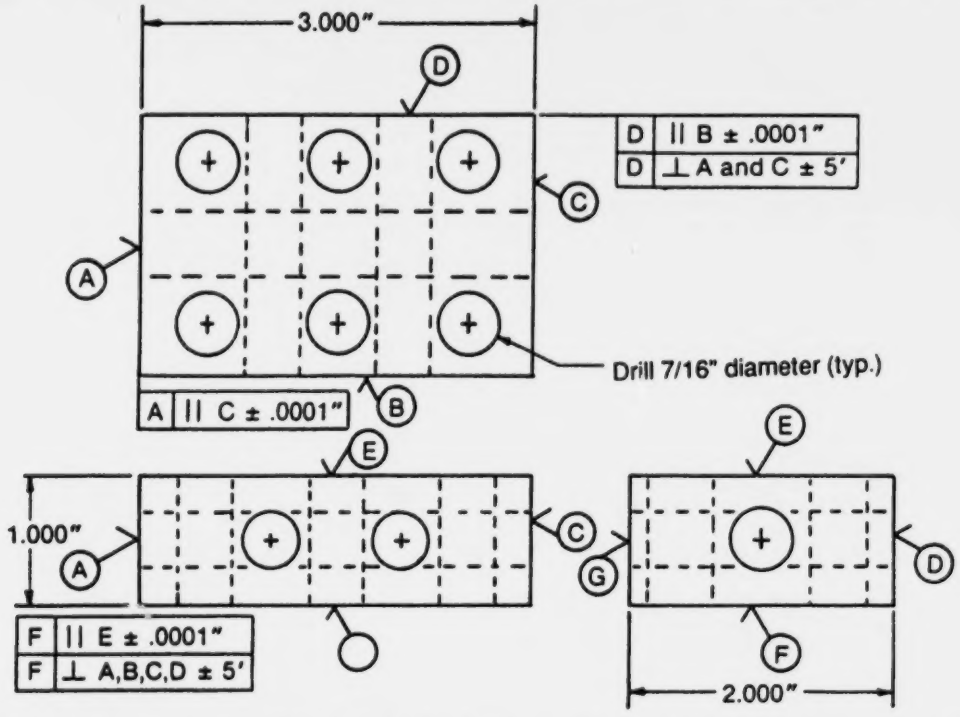


Credit: Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates. 1987. pg. 447.

GRINDING A SET OF SET-UP BLOCKS

Study the plans for the set-up block shown below; then complete the exercises that follow.

NOTES: Letters A through F are for surface reference only and do not indicate grinding sequence. Heat-treated and stress-relieved Finish #16 is used on all sides. All holes are countersunk 1/16" x 45°.



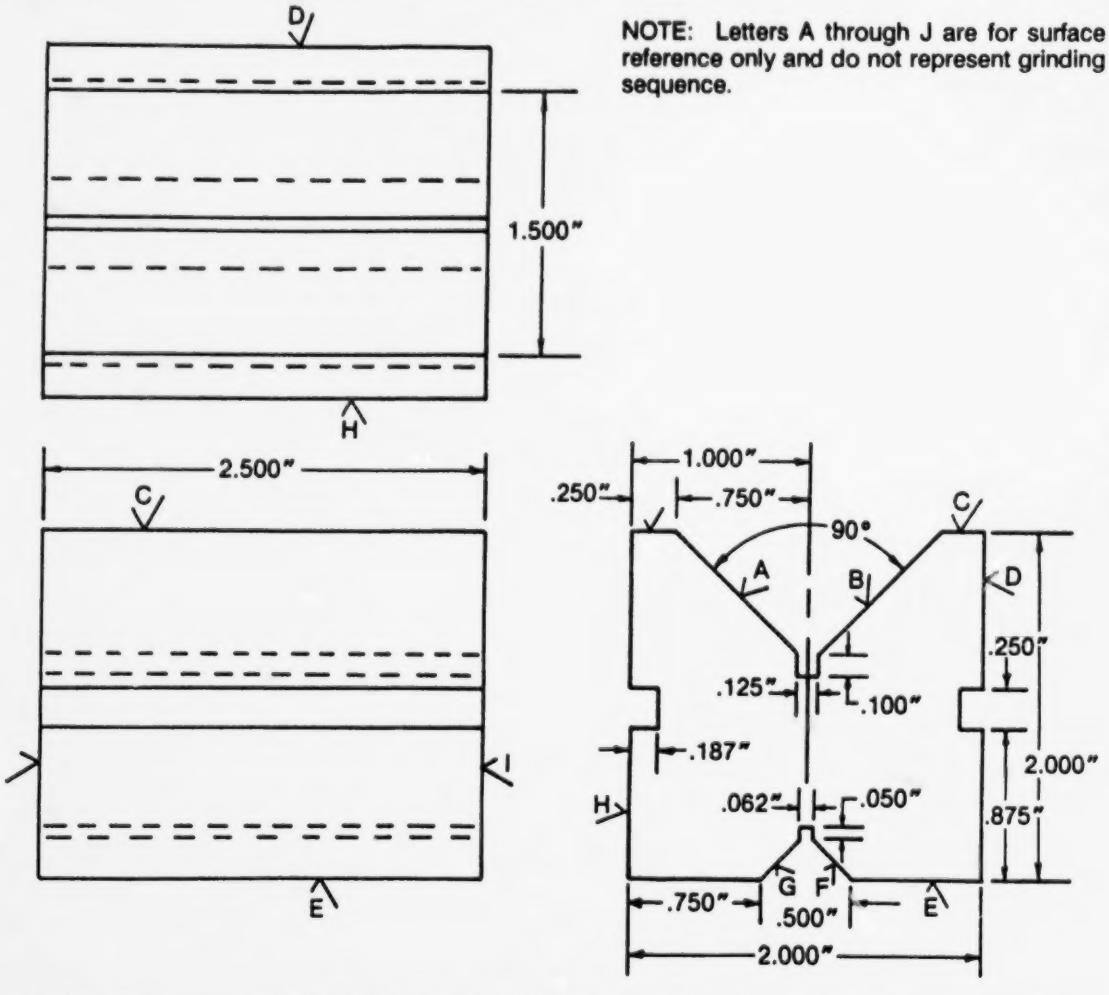
Credit: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 145.

1. List tools and work-holding devices required to grind blocks to finished dimensions. Assume that blocks have been scaled and drilled and that the machine being used is equipped with a magnetic chuck, coolant and a 32A46-J8VBE Type #1 wheel.

2. List procedures required to grind blocks to size. Assume that 0.20 inch of material remains to be ground from each surface.

GRINDING A V-BLOCK

Study the plans for the V-block below, then complete the exercises that follow.



NOTE: Letters A through J are for surface reference only and do not represent grinding sequence.

Credit: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 149.

1. List tools and equipment required to grind the V-block. Assume that workpiece is ready for final grinding with 0.020 inch of material left to be removed from each indicated surface. The grinding machine has a magnetic chuck, coolant and a 32A46-J8VBE Type #1 wheel.

2. List in order procedures required to grind the V-block.

ANSWERS TO AS 1.1

NOTE: Tools, equipment and procedures may vary depending on availability of tools and equipment and instructor's preference.

1. Angle plate (4-inch) with C-clamps
   Surface plate
   Adjustable parallels
   Height gage with indicator
   Dressing stick
   Dressing block and diamond
   Micrometer, 1- to 2-inch
   Micrometer, 2- to 3-inch
   Micrometer, 3- to 4-inch
   Soft oilstone
   Hard oilstone
   Grinding paper
   Ground parallel, 1"x2"x5"
   Small plastic mallet

2. Dress wheel flat; clean magnetic chuck.
   Check for burrs on surface of magnetic chuck; remove by honing if necessary; reclean work surface.
   Place side E or F of one block on magnetic chuck; grind opposite side.
   Perform same operation on second block.
   Deburr edges of surfaces just ground; clean magnetic chuck.
   Place ground surfaces of both blocks on magnetic chuck; grind to a dimension of 1.000 inch.
   Remove workpieces, clean chuck and deburr edges of surface just ground.
   Redress grinding wheel.
   Adjust the parallel to about 2 1/8 inches.
   Place angle plate on surface plate, place adjustable parallel on vertical surface of angle plate, place surface B or D on parallel and clamp block to angle plate.
   Place angle plate on chuck, grind surface B or D smooth and flat, remove angle plate from chuck and clean chuck.
   Unclamp block, clean angle plate and repeat steps with second block.
   Deburr edges and place both blocks on chuck so that surfaces just ground face downward.
   Grind blocks to a dimension of 2.000 inches. Remove them from chuck, clean chuck and deburr surfaces just ground.
   Redress grinding wheel.
   Place angle plate so that both faces are vertical on surface plate; slide adjustable parallel up to one of vertical surfaces; place surface B or D on parallel so that surface A or C is about 1/8 inch above top of angle plate; clamp in place.
   Remove adjustable parallel; check surface with dial indicator to see that it is parallel to surface plate; adjust if necessary.
   Place angle plate on chuck so that surface A or C is up. Grind the surface smooth and flat.
   Repeat steps on second block; deburr edges; clean chuck.
   Place surfaces just ground on magnetic chuck with the 1-by-2-inch parallel between the two blocks so that the 1-inch surface of parallel is on chuck.
   Hold the two blocks firmly against the parallel and energize chuck; clamp the blocks together.
   Grind the two surfaces to a dimension of 3.000 inches.
   Remove workpiece from chuck, unclamp and deburr surfaces just ground.
   Inspect workpieces.

ANSWERS TO AS 1.2

NOTE: The tools, equipment and procedures may vary depending on availability of tools and equipment and instructor's individual preferences.

1.
- Angle plate (4-inch) with ground sides
- C-clamps, 4-inch
- Adjustable parallels
- Height gage with indicator
- Dressing stick
- Dressing block and diamond
- Micrometer, 2- to 3-inch
- Soft oilstone
- Hard oilstone
- Grinding paper
- Small plastic mallet
- Parallel, 1/2" x 1" x 6"
- Magnetic V-block

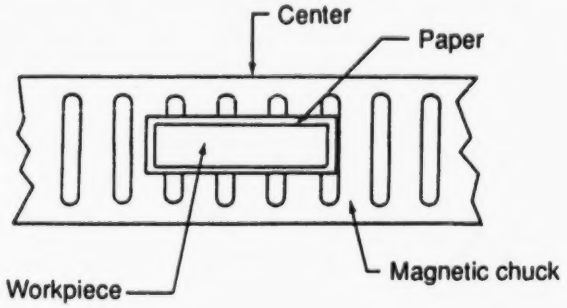
2. Dress wheel flat; clean magnetic chuck.
Check for burrs on surface of chuck; remove by honing if necessary; reclean work surface.
Place surface C or E on chuck; grind opposite side.
Place ground surface down; grind opposite side to dimension of 2.000 inches.
Place workpiece on angle plate with side E against vertical surface of angle plate and surface D or H parallel to surface plate; clamp in place.
Grind surface D or H, remove workpiece from angle plate and deburr edges of surfaces ground.
Place surface just ground on chuck. Grind opposite side to a dimension of 2.000 inches. Unchuck and deburr.
Clamp one of four ground sides to angle plate and align parallel to surface plate.
Grind surface I or J, remove workpiece from angle plate and deburr edges.
Place surface I or J on chuck; grind opposite surface to a dimension of 2.500 inches; unchuck and deburr.
Place magnetic V-block on magnetic chuck; align parallel to table travel; energize chuck to hold V-block true.
Place surfaces D and E in magnetic V-block and energize.
Grind surface B flat and smooth; zero the downfeed or note the setting.
Turn workpiece in magnetic V-block so that surfaces E and H are in "V"; energize V-block.
Grind surface A to same setting. (It may be necessary to turn workpiece and grind surface B again.)
Redress wheel flat.
Grind surfaces G and F using same procedures as those used for surface A and B.
Remove burrs from edges of ground surfaces.
Inspect workpiece for accuracy.

GRIND WORKPIECE ON MAGNETIC CHUCK USING POWER FEED

Equipment:

Grinding machine with power feeds in longitudinal and cross-feed directions, coolant and magnetic chuck (mounted)
Single-point diamond mounted in holder
Clean cloth or squeegee
Hard oilstone
Medium oilstone
Micrometer, 1- to 2-inch
Steel block (2" x 2" x 5" premachined square, heat-treated 55-60C)
Abrasive cloth, 120-grit, 2-by-6-inch
Type I grinding wheel (mounted)
Grinding paper
Pencil

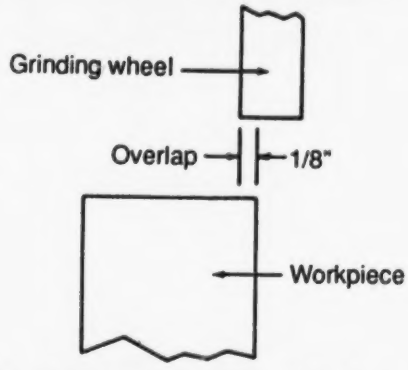
Procedure:	Evaluation 3	2	1	N
1. Dress grinding wheel wet.	—	—	—	—
2. Clean magnetic chuck and hone lightly to remove any burrs. Sand all sides of steel block to remove any scale caused by heat treatment.	—	—	—	—
3. Place a piece of grinding paper slightly larger than the workpiece in the center of the chuck. Place workpiece on paper with its length parallel to length of chuck; energize chuck; check workpiece to see that it is held securely.	—	—	—	—



Art credit for this job sheet: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 176-177.

4. Adjust table reverse dogs so that center of wheel clears each end of workpiece by 1".	—	—	—	—
5. Turn machine on; adjust table travel to 25 inches per minute.	—	—	—	—
6. Set cross-feed movement at 0.030 inch per table direction change. (Use manual method if necessary.)	—	—	—	—

7. Disengage power table feed and put cross-feed lever in neutral position. Adjust table by hand until edge of the wheel overlaps workpiece 1/8". — — — —



8. Start grinder and lower wheel slowly until it just sparks workpiece. Engage fine-feed knob and raise wheel 0.005 inch to clear any high spots on work. — — — —

9. Start coolant; allow it to run for one minute to stabilize wheel. — — — —

10. Move table longitudinally while feeding workpiece rapidly across face of wheel. — — — —

11. Move wheel so that it clears the back side of workpiece; lower wheel 0.005 inch. — — — —

12. Start table moving by power; engage cross-feed lever so that wheel will move over workpiece. Allow grinder to grind top surface. — — — —

13. Stop power table feed and cross-feed. Position table by hand so that wheel will not cut workpiece. — — — —

14. Crank cross-feed to back side of workpiece. Lower wheel 0.001 inch and make another cut. — — — —

15. Repeat steps 11 and 12 until surface is smooth. — — — —

16. Turn off coolant, stop table travel and allow wheel to run for one minute to remove coolant from pores of wheel. Stop machine. — — — —

17. Position wheel on back side of workpiece with table near left trip dog; mark location of workpiece with pencil. — — — —

CAUTION: Do not crank wheel over finished work; the wheel may scratch the surface.

18. Release workpiece and remove from magnetic chuck. Wipe chuck with clean rag or squeegee; then wipe with palm of hand to remove any dirt and to check for smoothness. — — — —

19. Place a clean piece of grinding paper on chuck. Use medium oilstone to remove burrs from edges just ground. — — — —

CAUTION: These burrs are sharp. Take care not to cut yourself.

20.	Place workpiece on grinding paper with ground side down; energize chuck and repeat procedure to grind second side flat.	—	—	—	—
	NOTE: Do not change adjustment of grinding-wheel height. You can start grinding from that point.				
21.	Check for parallelism by measuring all four corners of workpiece to a tolerance of ±.0002 inch. The micrometer reading should be the same in all locations. If workpiece is not true, you may need to redress wheel and regrind second side.	—	—	—	—
22.	Ask instructor to check your work.	—	—	—	—
23.	Clean machine and work area; put away all tools.	—	—	—	—
	Average of above evaluations*	—	—	—	—

*This average is the student's final evaluation for competency K8: Grind workpiece on magnetic chuck using power feed.

GRIND WORKPIECE SQUARE ON SURFACE GRINDER

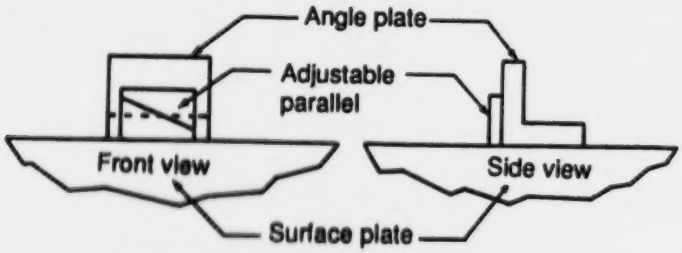
Equipment:

Surface grinder with magnetic chuck and coolant
Precision angle plate
Two C-clamps, 4-inch
Grinding paper
Single-point diamond mounted in holder
Dressing stick
Clean cloth or squeegee
Hard oilstone
Medium oilstone
Steel block
Type I 32A60-J8VBE or equivalent grinding wheel (mounted)
Surface plate
Adjustable parallels
Steel rule, 6-inch
Screwdriver to fit adjustable parallels
Micrometer, 1- to 2-inch

Procedure:		Evaluation 3	2	1	N
1.	Dress grinding wheel.	—	—	—	—
2.	Clean chuck and remove any burrs with hard oilstone; wipe top surface of chuck with your hand to remove any dirt and to check for smoothness.	—	—	—	—
3.	Place piece of grinding paper slightly larger than base of angle plate near center of magnetic chuck.	—	—	—	—
4.	Clean surface plate and place on clean cloth. Clean angle plate and check for burrs; remove any burrs with hard oilstone; place angle plate on surface plate.	—	—	—	—
5.	With steel rule, measure thickness of workpiece between surfaces ground in JS 1.1.	—	—	—	—
6.	Measure height of angle plate with steel rule; subtract workpiece thickness from angle plate height.	—	—	—	—
7.	Select an adjustable parallel with a range greater than difference between thickness of workpiece and height of angle plate; set adjustable parallel about 1/8" larger than that difference.	—	—	—	—

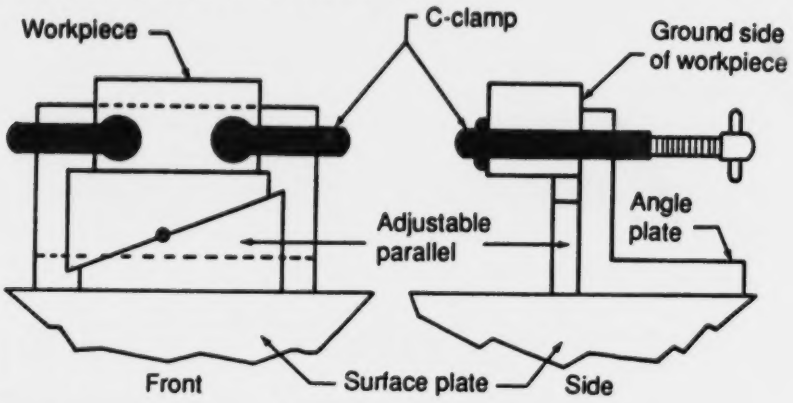
NOTE: The adjustable parallel will raise the workpiece above the top surface of the angle plate, placing it parallel to the magnetic chuck.

8. Place parallel on surface plate so that it is next to upright surface of angle plate. — — — —



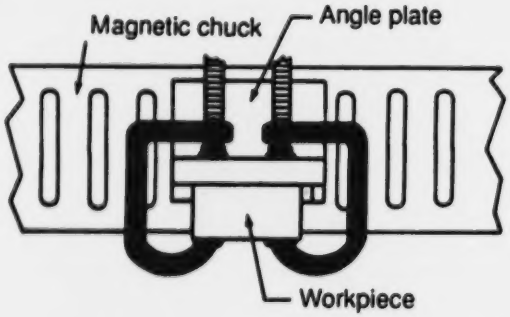
Art credit for this job sheet: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 180-191.

9. Place workpiece on adjustable parallel with one of the ground sides against upright surface of angle plate; hold it with one hand while clamping workpiece to angle plate with C-clamps. — — — —



10. Place angle plate on grinding paper so that its face is parallel to table travel; energize magnetic chuck. — — — —

NOTE: If permitted by instructor, the adjustable parallel may be used when grinding.



11. Adjust table reverse dogs so that wheel clears workpiece by one inch at each end. — — — —

12. Turn machine on and adjust table travel to 25 inches per minute. Set cross-feed movement at 0.030" per cut; place power feeds in neutral position. (Use manual method if necessary.) — — — —

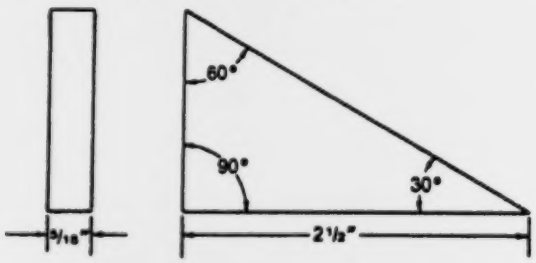
13.	Position workpiece under wheel so that 1/8" overlaps. Start grinder and turn on coolant.	—	—	—	—
14.	Lower wheel slowly until it sparks workpiece. Engage fine feed; raise wheel about 0.005".	—	—	—	—
15.	Hand feed wheel over surface of workpiece to check for high points. Move wheel to back side of workpiece.	—	—	—	—
16.	Lower wheel 0.005". Engage power feed; grind top surface.	—	—	—	—
17.	Move wheel to back side again and lower wheel 0.001". Make another cut; continue to make cuts until surface is smooth.	—	—	—	—
18.	Stop machine and reposition table to clear set-up from wheel. Remove angle plate; remove workpiece from angle plate.	—	—	—	—
19.	Clean chuck and remove burrs from workpiece. Place grinding paper on chuck and place workpiece on paper with unground surface up.	—	—	—	—
20.	Readjust reversing dogs if necessary and grind surface flat.	—	—	—	—
21.	Remove workpiece from chuck; measure width of workpiece between first two sides ground. Measure width of workpiece between second two sides ground and subtract the difference; mark the wider side.	—	—	—	—
22.	Clean chuck and place workpiece on clean grinding paper with one of narrower surfaces up.	—	—	—	—
23.	Energize chuck and use fine-feed adjustment to raise wheel a distance equal to the difference in the two widths of workpiece.	—	—	—	—
24.	Position workpiece under wheel; move wheel down until it just sparks workpiece. Grind off an amount equal to the difference in the two widths using cuts of 0.001" or less.	—	—	—	—
25.	Remove workpiece, deburr and turn in workpiece to instructor for evaluation.	—	—	—	—
26.	Clean machine and work; put away all tools.	—	—	—	—
Average of above evaluations*		—	—	—	—

*This average is the student's final evaluation for competency K9: Grind workpiece square on surface grinder and K10: Indicate workpiece to be ground.

GRIND ANGULAR SURFACES

Equipment:

Surface grinder with magnetic chuck and coolant
Sine bar, 5-inch
Angle plate, 4-inch
Gage blocks (81-piece set)
Two C-clamps, 4-inch
Dial indicator and height gage
Type I 32A46-J8VBE or equivalent grinding wheel (mounted)
Single-point diamond mounted in holder
Dressing stick
Hard oilstone
Medium oilstone
Clean cloth
Premachined material, heat-treated and tempered to 58 RC ± 2



Art credit for this job sheet: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 185, 187-190.

Surface plate
Steel rule, 12-inch
Sandpaper
Soft-faced mallet
Grinding paper

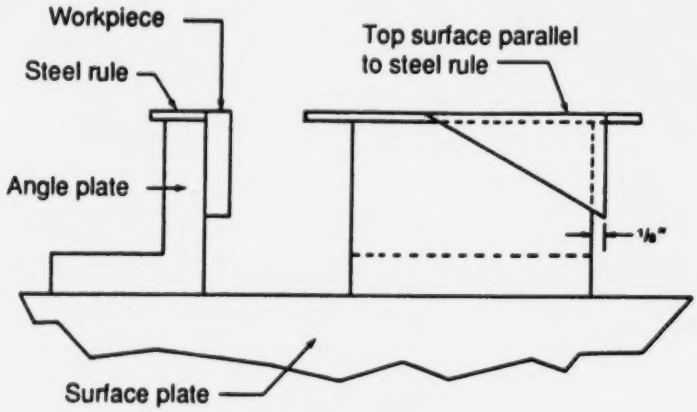
Procedure:		Evaluation 3	2	1	N
1.	Dress grinding wheel.	—	—	—	—
2.	Clean chuck and remove burrs with hard oilstone; wipe with hand to remove dirt. Clean scale from workpiece with sandpaper.	—	—	—	—
3.	Place one of the flat sides of workpiece down on chuck, energize chuck and grind that side smooth.	—	—	—	—
4.	Remove workpiece from chuck and deburr; clean chuck.	—	—	—	—
5.	Place ground side of workpiece down; energize chuck. Grind second side smooth and parallel to first side.	—	—	—	—
6.	Remove workpiece from chuck and deburr; clean chuck.	—	—	—	—

7. Place piece of grinding paper slightly larger than base of angle plate near center of chuck. Clean surface plate and angle plate. — — — —

8. Place base of angle plate on surface plate. Mount test indicator in height gage; clean base of height gage and place on surface plate. — — — —

9. Place steel rule on top surface of angle plate so that edge is even with length and face of angle plate. Place one side of ground angle on face of angle plate with long side of 90° angle up and even with steel rule. Short side of 90° angle should be 1/8" past edge of surface plate. — — — —

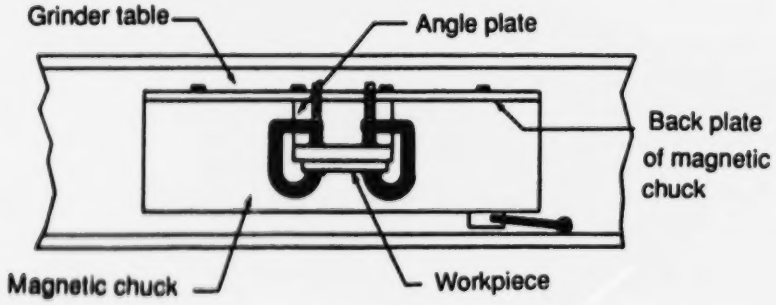
NOTE: This position will allow the angle plate to be laid on its side to grind the other side of the 90° angle.



10. Clamp workpiece to angle plate with one clamp; remove steel rule. — — — —

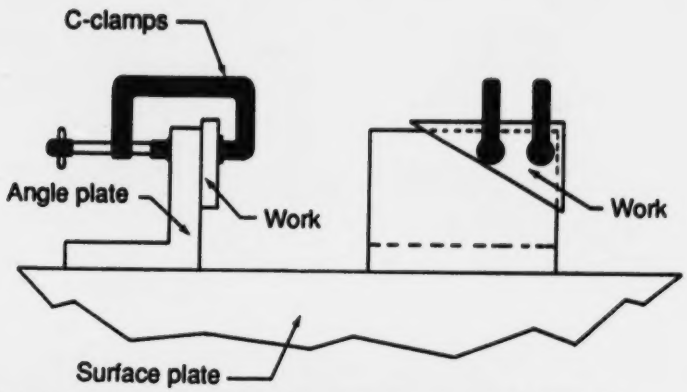
11. Use test indicator to check top surface of workpiece. It must be within 0.003" of parallel to top surface of surface plate; adjust with soft-faced mallet if necessary. — — — —

12. Place second clamp on workpiece and secure. Set angle plate on magnetic chuck with length parallel to table. — — — —



13. Grind top edge smooth and flat. — — — —

14. Remove angle plate from chuck; wipe grinding particles from it and the chuck. — — — —

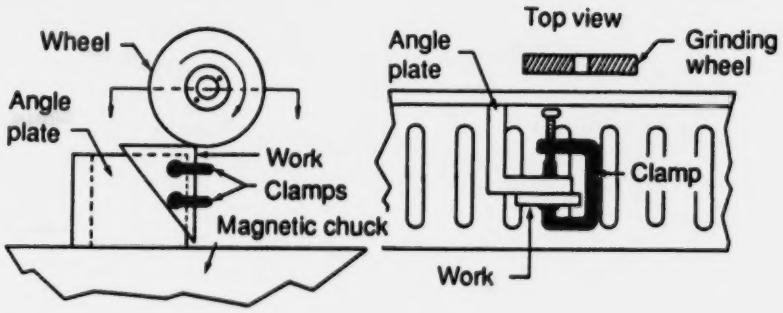


15. Place base of angle plate on surface plate. Reposition clamp near 30° angle of workpiece so that clamp frame is over surface just ground; retighten clamp, then reposition other clamp frame over top surface just ground. — — — —

16. Check ground surface with indicator. This surface should be within 0.0001" of parallel to surface plate at each end. Adjust if necessary. — — — —

17. Place side of angle plate on chuck so that short side of 90° angle of workpiece is up. Readjust and position grinding wheel. — — — —

18. Grind top surface smooth and flat. — — — —

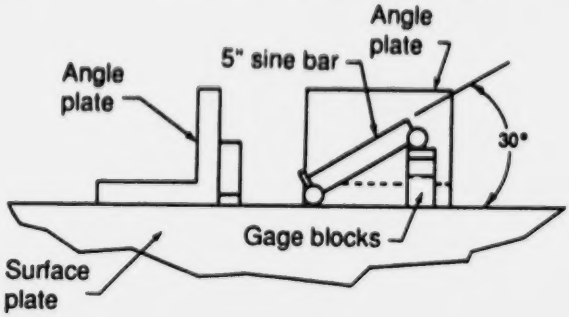


19. Remove angle plate from chuck; clean chuck. Unclamp and deburr workpiece; clean angle plate. — — — —

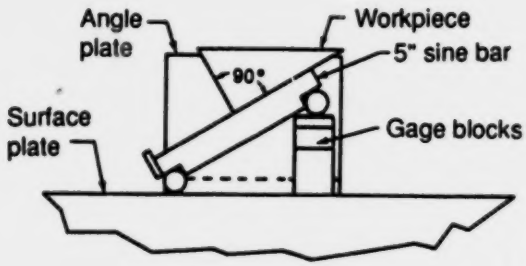
20. Set base of angle plate on surface plate. — — — —

21. Set sine bar against angle plate, using gage blocks to raise one end to 2.5". — — — —

NOTE: Sine-bar setting is determined by multiplying sine of angle times length of sine bar; in this case, 0.5 x 5 = 2.5".



22. Place workpiece on sine bar with long side of 90° angle on surface of sine bar and against angle plate. Unground surface will be 1/8" above top of angle plate. — — — —



23. Place C-clamps on workpiece so that top surface can be ground; remove sine bar and gage blocks. — — — —

24. Place angle plate on clean grinding paper in center of chuck; energize chuck. — — — —

25. Adjust wheel and grind surface smooth and flat. — — — —

26. Remove angle plate from chuck and remove workpiece from angle plate; clean angle plate. — — — —

27. Hone sharp edges of workpiece and turn in workpiece to instructor for evaluation. — — — —

28. Clean machine; put away all tools. — — — —

Average of above evaluations* — — — —

*This average is the student's final evaluation for competency K11: Grind angular surfaces.

MODULE: GRINDERS

UNIT IV: SURFACE GRINDING FLAT AND ANGULAR SURFACES

UNIT TEST

Match the following terms with definitions.

____ 1.	Internal strain in the workpiece	a.	Cross
____ 2.	Moving alternately back and forth	b.	Energize
____ 3.	Movement of grinding wheel from back to front during grinding operation	c.	Flat
____ 4.	Surface that is straight and free of warps or bows	d.	Reciprocating
____ 5.	Carbon or other impurities on the steel surface	e.	Scale
____ 6.	To apply power to the magnetic device	ab.	Stone the chuck
____ 7.	To remove burrs by rubbing surface	ac.	Stress
____ 8.	Appearance or degree of workpiece smoothness	ad.	Surface finish

Select the option which answers the question or completes the statement.

____ 9. To remove a small burr from the surface of the magnetic chuck, what should be done?

a. Replace the chuck.
b. Grind the chuck.
c. Stone the chuck.
d. Indicate the chuck.
e. All of the above

____ 10. What should be done when grinding small workpieces?

a. Always block in around the part.
b. Never take more than .0001" cut.
c. Always secure in a vise.
d. Use a dish wheel.
e. All of the above

____ 11. When touching off to the workpiece, what should the operator do?

a. Touch off the highest point of surface to be ground.
b. Touch off using .001 brass feeler gage.
c. Set automatic depth gage to locate and touch off.
d. Indicate the workpiece.
e. None of the above

___ 12. A dial test indicator is useful in checking which of the following?

a. Run out of the grinding wheel
b. Machine level
c. Parallelism of part
d. Longitudinal movement
e. All of the above

___ 13. How does an operator prepare the workpiece before mounting onto the magnetic chuck?

a. Soak it in water-soluble oil.
b. Maintain room temperature.
c. Wax the mounting surface of workpiece.
d. Examine workpiece and remove burrs.
e. All of the above

___ 14. What is the workpiece mounted over to ensure that it is held securely onto the magnetic chuck?

a. One-half of backstop
b. One steel section
c. Two steel sections
d. Three or more steel sections
e. None of the above

___ 15. To quickly locate the angle plate square onto magnetic chuck, the surface is placed against which of the following?

a. Back plate
b. Front plate
c. End plate
d. Side plate
e. None of the above

___ 16. What tool is used to position the workpiece slightly above the top of the angle plate?

a. Surface locator
b. Parallels
c. Dial indicator
d. Magnetism
e. None of the above

___ 17. When setting table longitudinal stops, what distance (inches) should the overrun be set past the workpiece?

a. .250 to .500
b. .500 to .750
c. .750 to 1.000
d. 1.250 to 1.500
e. None of the above

___ 18. Which of the following considerations is <u>not</u> used to determine if a grinding operation can be carried out with a single dressing of the wheel?

a. Surface finish requirements
b. Surface area of face to be ground
c. Height of workpiece to be ground
d. Amount of material to be removed
e. All of the above

___ 19. To rough out a workpiece, how much downfeed is used (approximate inches)?

a. .005
b. .002
c. .001
d. .0005
e. None of the above

___ 20. To finish grind a workpiece, how much downfeed is used (approximate inches)?

a. .002
b. .001
c. .0005
d. .0001
e. None of the above

___ 21. After grinding a workpiece to thickness, what does <u>not</u> need to be inspected?

a. Squareness
b. Flatness
c. Parallelism
d. Surface finish
e. All of the above

___ 22. To set up a sine bar, what is used to set the height required?

a. Parallels
b. Precision rules
c. Dial micrometer
d. Gage blocks
e. None of the above

___ 23. To clear the angle plate when setting a workpiece, how far above the angle plate should the workpiece be?

a. 1"
b. 1/2"
c. 1/8"
d. 1/64"
e. None of the above

___ 24. To inspect for flatness, what is the workpiece mounted onto?

a. Jacks
b. V-blocks
c. An angle plate
d. A magnetized chuck
e. None of the above

ANSWERS TO UNIT TEST

1.	ac	(K8)
2.	d	(K8)
3.	a	(K8)
4.	c	(K8)
5.	e	(K8)
6.	b	(K8)
7.	ab	(K8)
8.	ad	(K8)
9.	c	(K8)
10.	a	(K8)
11.	a	(K8)
12.	c	(K8)
13.	d	(K8)
14.	d	(K8)
15.	a	(K8)
16.	b	(K11)
17.	a	(K9)
18.	c	(K9)
19.	b	(K10)
20.	c	(K10)
21.	a	
22.	d	(K11)
23.	c	(K11)
24.	a	(K9)

MODULE: GRINDERS

UNIT V: CYLINDRICAL GRINDING

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to set up and operate the cylindrical grinder; mount, balance and dress a grinding wheel; grind work between centers; and regulate wheel speed, work speed and rate of table travel. This knowledge will be evidenced through demonstrations and by achieving specified scores on the unit test.

SPECIFIC OBJECTIVES

After completing the lessons in this unit, the student should be able to:

1.1 Match terms and definitions associated with cylindrical grinding.

1.2 Identify cylindrical grinding operations.

1.3 Arrange in order the procedures for removing and replacing a grinding wheel.

1.4 Arrange in order the steps for a cylindrical grinding wheel.

1.5 Name the types of wheel dressers.

1.6 Identify accessories used with cylindrical grinders.

1.7 Match cylindrical grinder accessories to functions.

2.1 Select probable causes of grinding problems.

2.2 Determine work rotation with respect to wheel rotation.

2.3 Calculate wheel speed (rpm), work speed and rate of table travel (ipm).

2.4 Remove and replace a grinding wheel. (competency K12, JS 2.1)

2.5 Use table-mounted holder to dress a grinding wheel. (competency K12, JS 2.2)

2.6 Grind workpiece between centers using cylindrical grinding. (competency K12, JS 2.3)

MODULE: GRINDERS

UNIT V: CYLINDRICAL GRINDERS

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: ACCESSORIES AND OPERATIONS

   a. Information outline

   b. Transparency masters

      TM 1.1: Parts of the headstock
      TM 1.2: Parts of the upright and controls
      TM 1.3: Controls: right front and center front
      TM 1.4: Parts of the swivel and footstock

   c. Assignment sheets

      AS 1.1: Identify operations and functions of parts
      AS 1.2: Removing, replacing and dressing a cylindrical grinding wheel

   d. Answers to assignment sheets

2. Lesson 2: GRINDING PROBLEMS, CALCULATIONS AND TECHNIQUES

   a. Information outline

   b. Assignment sheets

      AS 2.1: Calculate wheel speed, work speed and rate of table travel
      AS 2.2: Plan procedures for grinding a tapered mandrel

   c. Answers to assignment sheets

   d. Job sheets

      JS 2.1: Remove and replace a grinding wheel
      JS 2.2: Use table-mounted holder to dress a grinding wheel
      JS 2.3: Grind workpiece between centers

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Kibbe, Richard R., et. al. Machine Tool Practices. New York: John Wiley and Sons, 1979.
2. Krar, S. F. and J. W. Oswald. Grinding Technology. Albany, NY: Delmar Publishers, Inc., 1984.
3. Krar, S. F., J. W. Oswald and J. E. St. Amand. Technology of Machine Tools. 3rd ed. Toronto: McGraw-Hill, 1984.
4. Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987.

B. Curriculum guides

1. Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983.
2. Machinist. Frankfort, KY: Vocational-Technical Education Consortium of States, 1982.
3. Yettaw, Jerome. Vocational Machine Shop. University of Missouri-Columbia: Instructional Materials Laboratory, 1977.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Instructors can use the assignment sheet in this unit in several ways.
   a. As a student guide to procedures being worked through in class by the instructor
   b. As a student guide when performing a practice procedure
   c. As an evaluation instrument to determine if students have memorized steps of procedure
2. Demonstrate proper set-up and operation of a cylindrical grinder. Students can also benefit from observing the proper method of grinding a workpiece straight and to size.

B. Suggested supplemental materials

1. Operation and Maintenance Manual of the 618 and 818 Micromaster Series II Surface Grinding Machines. North Kingstown, RI: Brown and Sharpe Co., 1980.
2. Oberg, Erik; Franklin D. Jones; Holbrook L. Horton. Machinery's Handbook. 23rd ed. New York: Industrial Press, Inc., 1988.

MODULE: GRINDERS

UNIT V: CYLINDRICAL GRINDERS

LESSON 1: ACCESSORIES AND OPERATIONS

I. Terms and definitions

A. Automatic feed--movement of table or work head by hydraulic and/or mechanical feed

B. Dead center--center that does not revolve

C. Dwell or tarry time--pause at one or both ends of table to permit grinding wheel to grind workpiece to size and to provide for feed completion before table reverses direction

D. Feed index--mechanical feed device that allows for adjustment of feed depth

E. ID (inside diameter) grinding--grinding on inside of workpiece to enlarge a bore or hole

F. Internal cylindrical grinder--cylindrical grinder designed especially for ID grinding

G. Live center--center that revolves with workpiece

H. OD (outside diameter) grinding--grinding on outside circumference of round workpiece

I. Plain cylindrical grinder--cylindrical grinder with headstock and work head that are fixed; used to perform OD, straight and taper grinding

J. Universal cylindrical grinder--cylindrical grinder with headstock and work head that can be swiveled; used to perform OD, ID and face grinding

K. Wheel speed (rpm)--number of revolutions per minute (rpm) that grinding wheel turns

CAUTION: The wheel speed should not exceed that of the manufacturer's marking.

NOTE: Wheel should turn as close as possible to recommended maximum speed. As wheel wears, speed should be increased, if possible.

L. Work feed--rate wheel is fed into workpiece each time table reverses

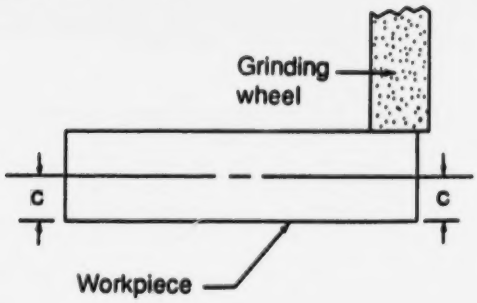
NOTE: Machines with automatic feeds can be set to feed right, left or both right and left.

M. Work rotation--rotation of workpiece at desired rate in opposite direction of grinding wheel

N. Work speed--number of revolutions per minute (rpm) that workpiece should turn to give correct surface speed and to obtain maximum wheel life, chip removal and desired finish

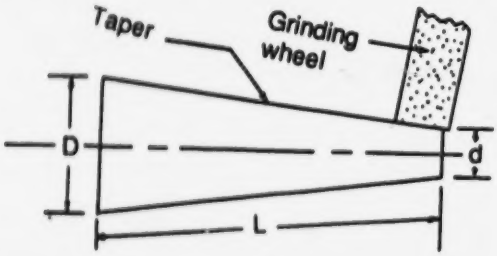
II. Cylindrical grinding operation

A. Straight grinding--working a cylindrical surface to an accurate size and finish with sides parallel to center axis throughout its length

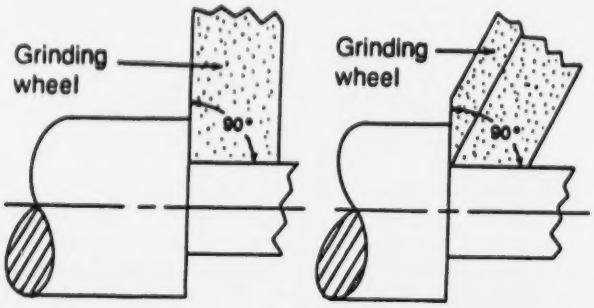


Art credit for this lesson: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 244-251, 259, 261, 263 and 265. Used by permission.

B. Taper grinding--grinding a conical surface that changes in diameter at a constant rate along its axis

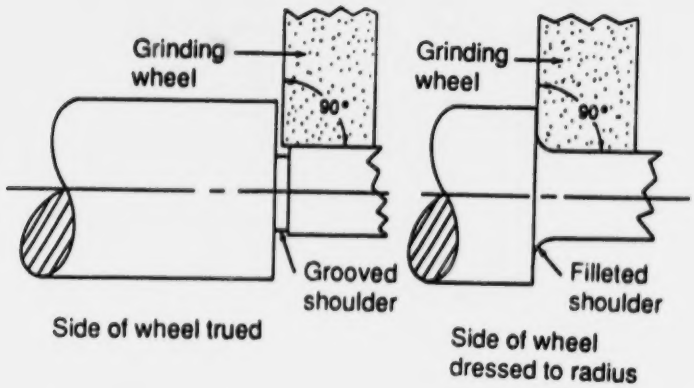


C. Shoulder grinding--grinding a surface 90° to axis of workpiece. Shoulders can be ground with the side of the wheel or by turning wheel head and dressing a 90° angle on the wheel. Shoulders that are deeper than one-half the width of the wheel can be ground by cross-feeding.

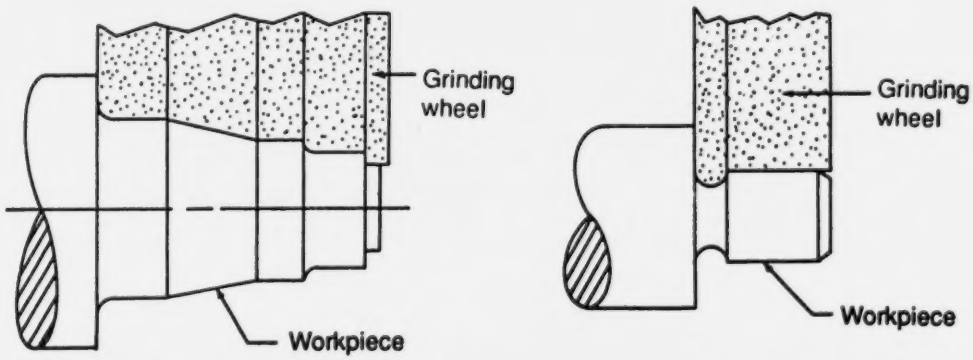


Side of wheel trued

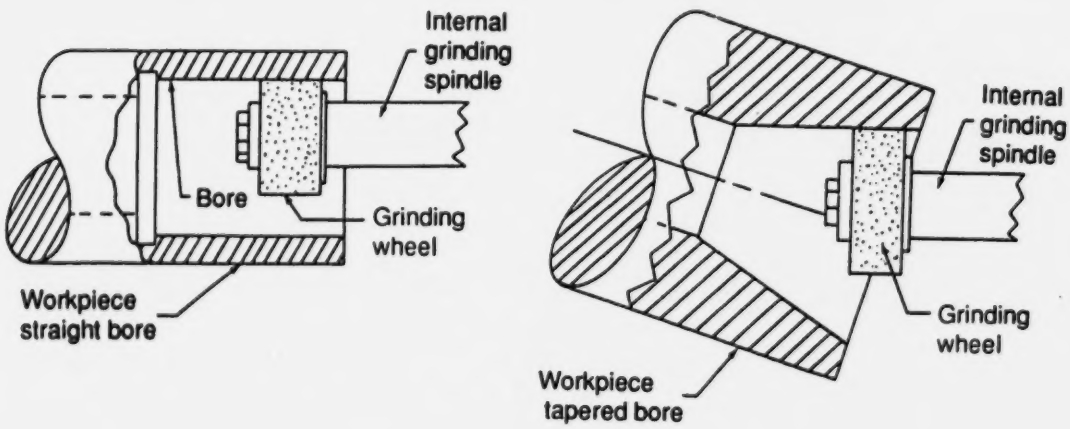
Wheel turned and dressed to 90-degree angle



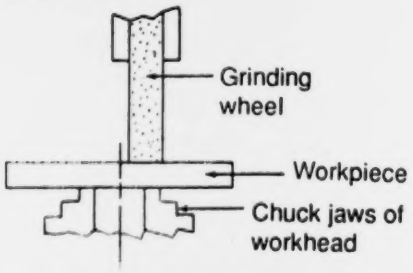
D. Contour (form) grinding--grinding a surface to a particular shape by means of a grinding wheel dressed to produce the desired shape



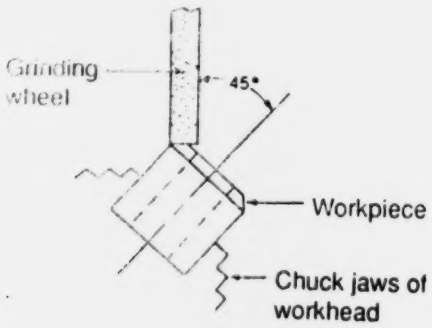
E. Internal grinding--grinding a hole or bore to an accurate size, taper or finish. This is performed on an internal grinding machine, universal grinding machine with internal grinding spindle or a tool-post grinder mounted to the compound of an engine lathe.



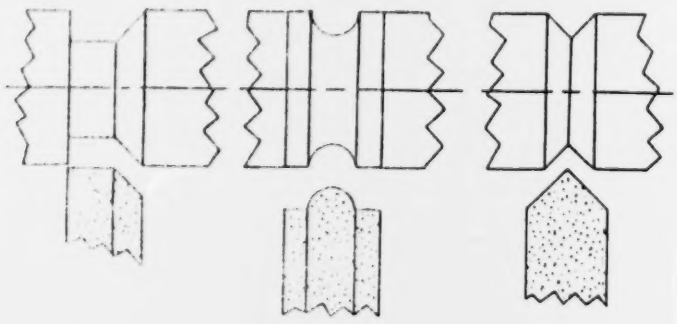
F. Face grinding--grinding end of workpiece by rotating surface to be ground at a 90° angle to grinding wheel (see below). Slight angles for purpose of relief can be face ground by setting the headstock at angles slightly less than 90°.



G. Angular grinding--grinding an angle by rotating work head at desired angle to grinding wheel. This operation is usually done on a universal-type grinding machine.



H. Plunge or infeed grinding--grinding a surface or shape by feeding wheel into workpiece with cross feed, can be performed on external or internal surfaces. Contour grinding is done by plunge or infeed grinding.



III. Procedures for removing and replacing a grinding wheel

A. Removing wheel

1. Remove outer portion of wheel guard.
2. Take off spindle nut. Most spindles have a left-hand thread.
3. Use wheel sleeve puller to loosen sleeve.

4. Remove puller and slide sleeve from tapered spindle.

5. Use wrench to remove sleeve from wheel.

6. Store wheel if it is not damaged; otherwise, discard.

B. Mounting wheel

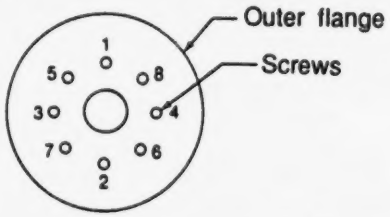
1. Clean spindle and surface of fixed flange and/or wheel sleeve.

2. Ring test the grinding wheel.

3. Slide wheel and blotters onto wheel sleeve.

4. Place outer flange on sleeve, place screws in holes of outer flange and finger-tighten all screws.

5. Use torque wrench or wrench provided by manufacturer to tighten all screws snugly in an alternating sequence.



NOTE: Numbers indicate alternating sequence of tightening.

6. Check wheel balance; balance if necessary.

7. Place sleeve on spindle and secure spindle nut. Some sleeves are keyed to spindle.

8. Replace wheel guard.

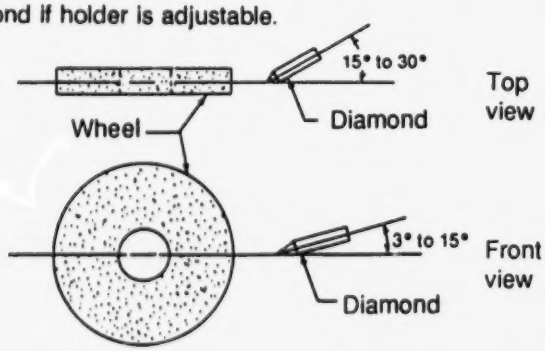
9. Stand to one side, jog start grinder and allow wheel to reach operating speed and run for one minute. After 8-12 hours of grinding, retighten screws to allow for blotter compression.

10. Clean machine and put away tools.

IV. Steps for dressing a cylindrical grinding wheel

A. Clamp diamond in holder. Holder may be mounted to table or part of the footstock.

B. Position diamond if holder is adjustable.



C. Start grinder and allow spindle bearings to warm up.

D. Feed wheel so that diamond contacts the point of largest diameter on the grinding-wheel surface.

E. Set table travel at 5-10 inches per minute (ipm) or set in truing position indicated by manufacturer.

F. Turn on coolant if necessary. Wheel should be dressed the same as it will be used--wet or dry.

G. Advance wheel 0.0005 inch for each pass across wheel until face of wheel is completely dressed.

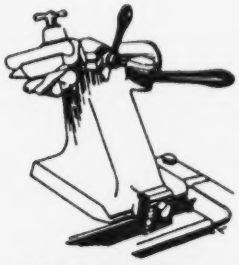
H. Position dresser so that it is clear of wheel.

I. If coolant was used, shut off coolant and allow rotation to continue for one minute before stopping wheel. Stop wheel.

J. Remove diamond and holder if required.

K. Clean dust from tools and equipment.

V. Types of wheel dressers



Footstock-mounted dresser

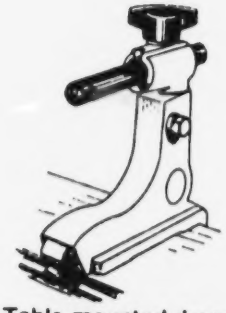
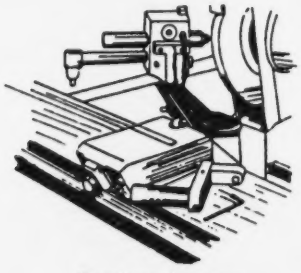
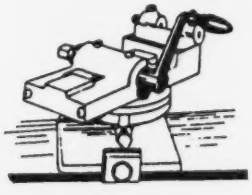


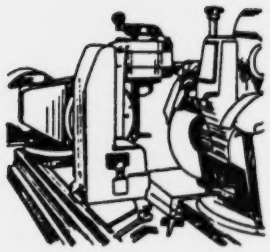
Table-mounted dresser



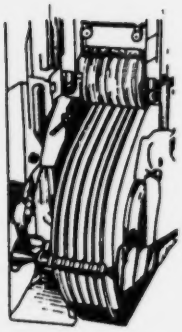
Radius dresser



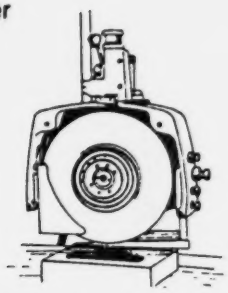
Angle dresser



Radius and tangent dresser



Crush roll dresser

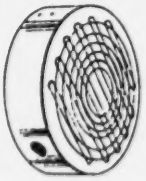


Built-in dresser

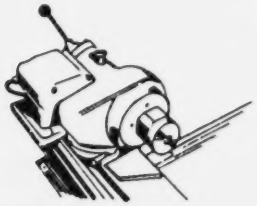
VI. Accessories used with cylindrical grinders **(TM 1.1-1.4)**

Three-jaw chuck

Four-jaw chuck

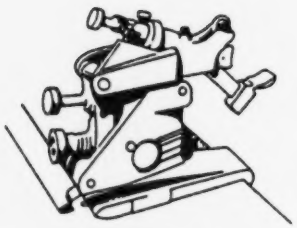


Magnetic chuck

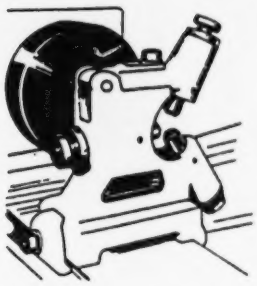


Collet chuck

T-slot faceplate

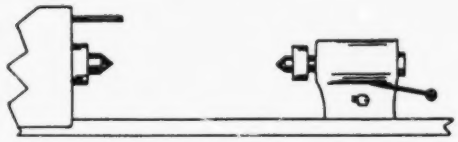


Universal backrest with adjustable shoe



Center rest

Driving dogs



Headstock and footstock centers

VII. Accessory functions

A. Chucks hold and drive workpieces for external or internal grinding operations.

B. Faceplates hold and drive workpieces for grinding operations that cannot be chucked; they also allow for fixture mounting.

C. Collet chucks hold and drive workpieces for external grinding operations of small workpieces that do not vary in size and allow quick clamping.

D. The magnetic chuck holds and drives thin workpieces for face grinding that cannot be chucked in a conventional chuck.

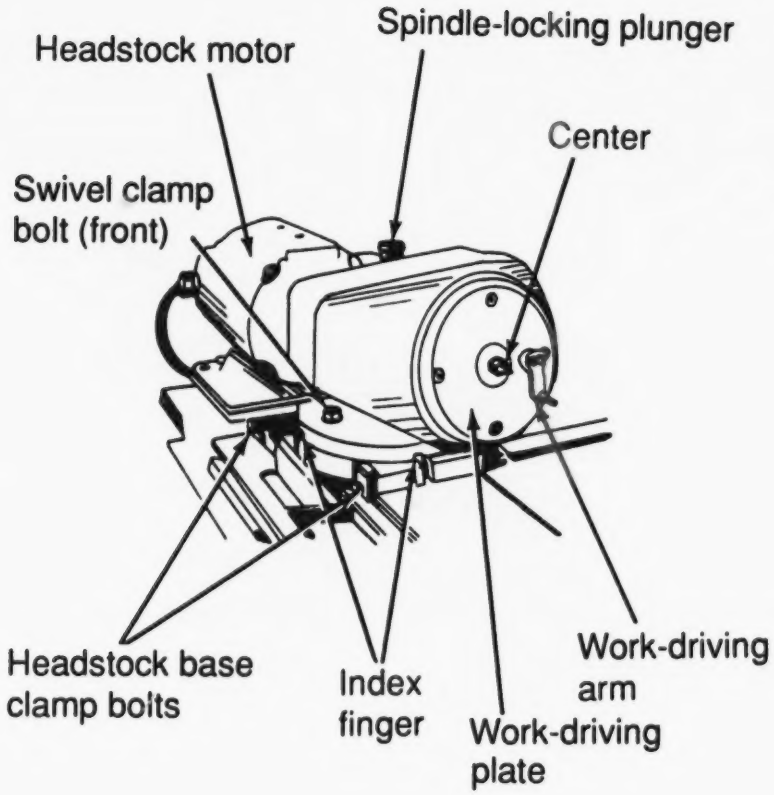
E. The center rest supports long workpieces for external or internal grinding operations.

F. The universal backrest with adjustable shoe support long workpieces so that accuracy can be maintained and chatter can be eliminated during grinding operation.

G. Headstock and footstock centers support the workpiece at each end for external grinding operations.

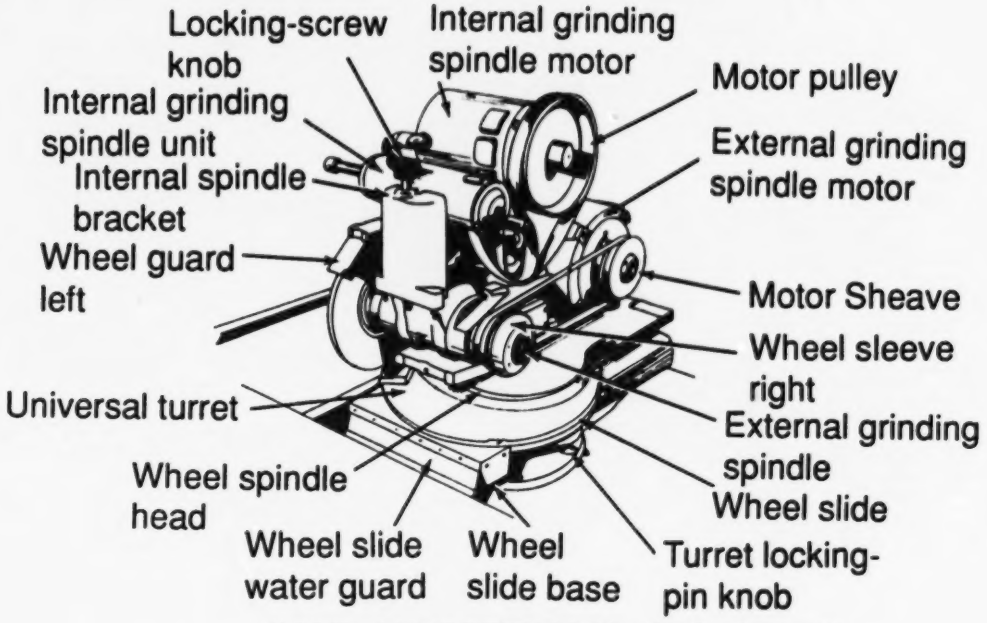
H. Driving dogs drive the workpiece held between centers.

PARTS OF THE HEADSTOCK

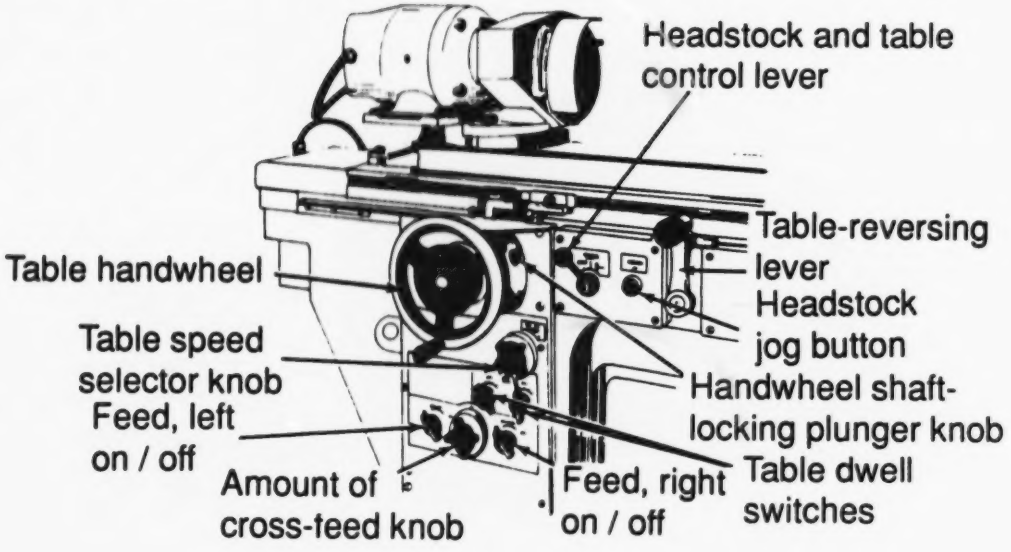


Credit: Brown and Sharpe Manufacturing Company

PARTS OF THE UPRIGHT . . .

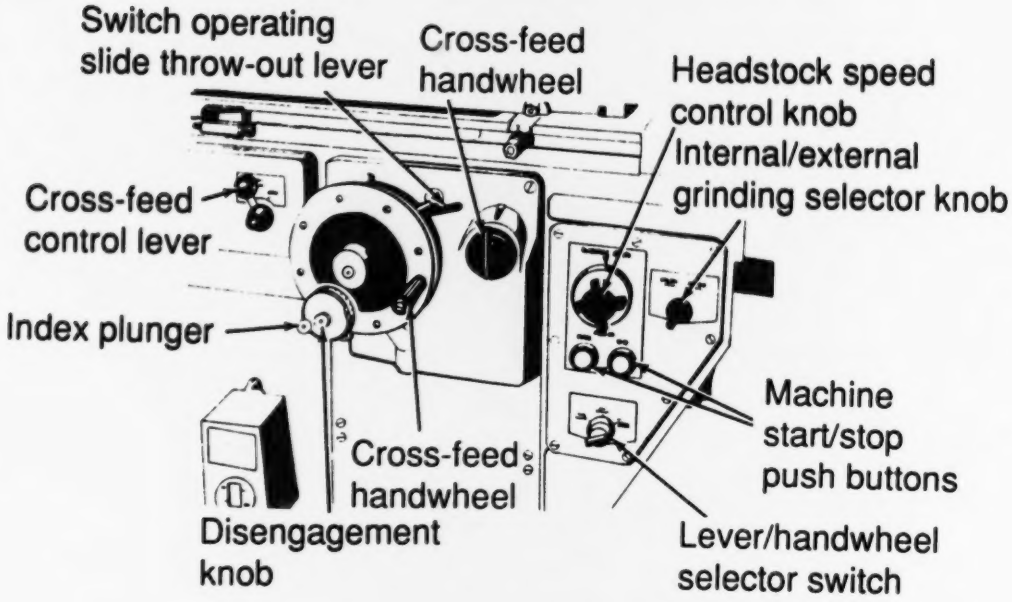


. . . AND CONTROLS (left front)

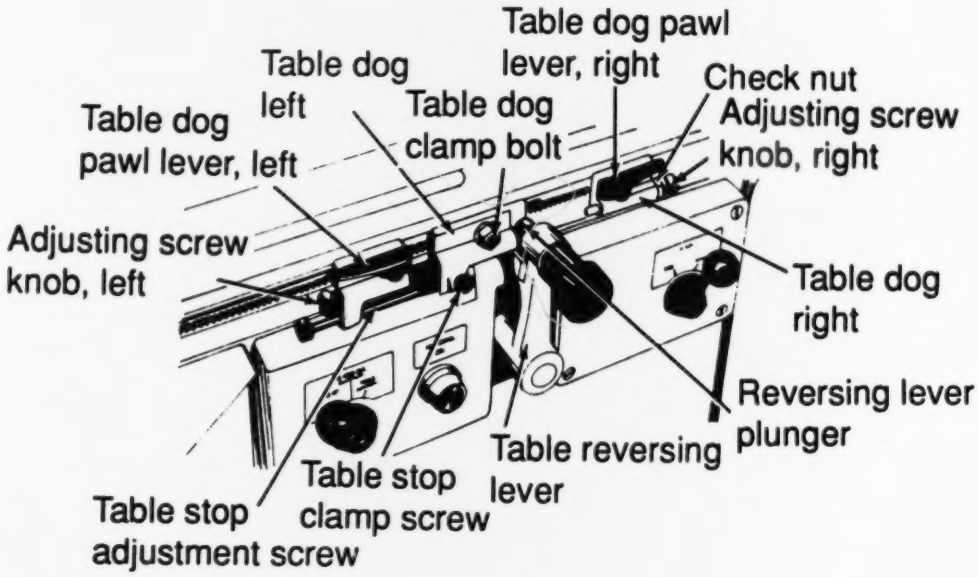


Credit: Brown and Sharpe Manufacturing Company

CONTROLS: RIGHT FRONT . . .

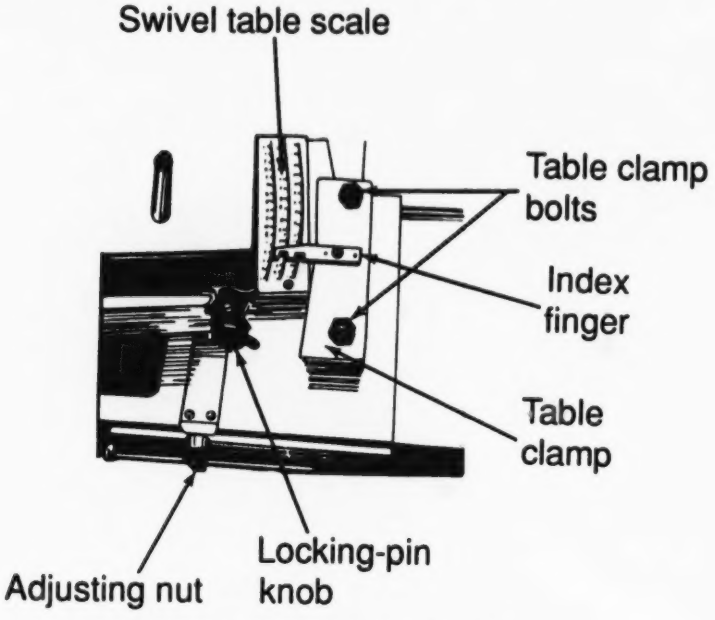


. . . AND CENTER FRONT

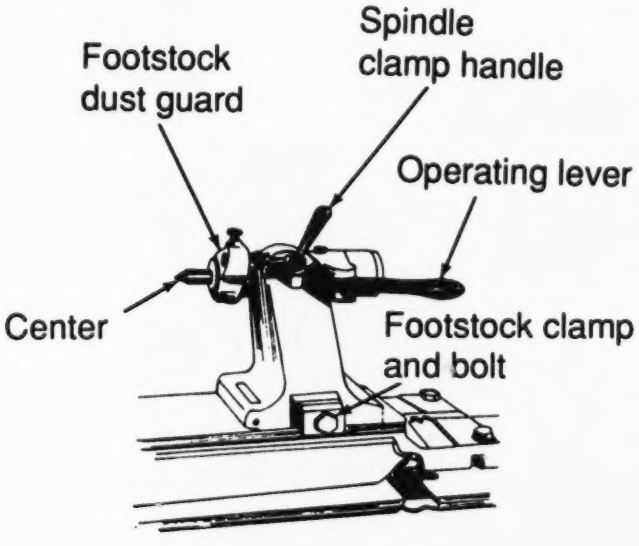


Credit: Brown and Sharpe Manufacturing Company

PARTS OF THE SWIVEL . . .



. . . AND FOOTSTOCK



Credit: Brown and Sharpe Manufacturing Company

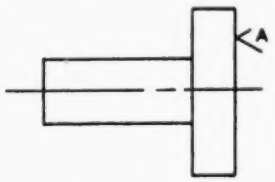
IDENTIFY CYLINDRICAL GRINDING OPERATIONS

In the blanks provided, identify type of cylindrical grinding operation described and illustrated below.

NOTE: Some illustrations may represent more than one type of operation. Answers may be used more than once.

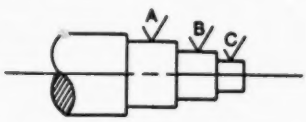
a.	Straight grinding	e.	Internal grinding
b.	Taper grinding	ab.	Face grinding
c.	Shoulder grinding	ac.	Angular grinding
d.	Contour grinding	ad.	Plunge or infeed grinding

___ 1. Grinding surface A 90° to center axis of workpiece

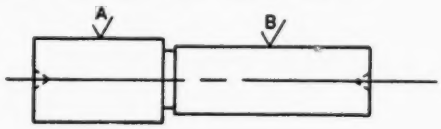


Art credit for this assignment sheet: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 267-270. Used by permission.

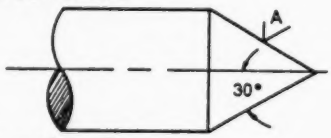
___ 2. Grinding surfaces A, B and C at one time so that all surfaces are concentric to center axis



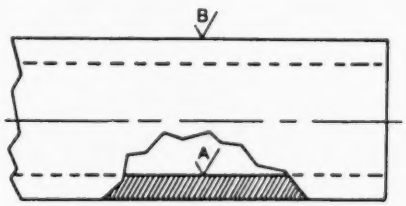
___ 3. Grinding surfaces A and B true to center axis of shaft



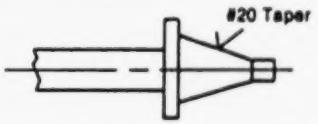
___ 4. Grinding surface A 30° to center axis



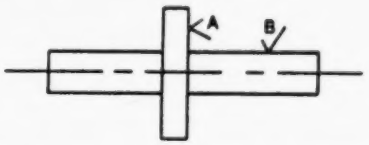
___ 5. Grinding surface A true to surface B



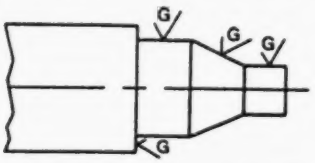
___ 6. Grinding a #20 machine taper on the end of an arbor



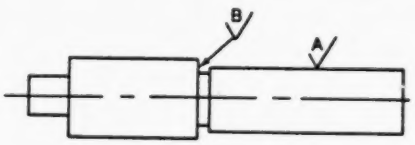
___ 7. Grinding surface A 90° to surface B



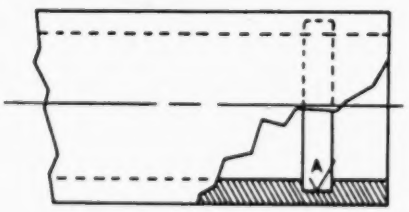
___ 8. Grinding the shape indicated true to center axis of workpiece



___ 9. Grinding surfaces A and B so that A is true to center and B is 90° to A



___ 10. Grinding surface concentric to bore



Match major parts of a cylindrical grinder to functions.

___ 11. Regulates direction of table movement by striking table-reversing lever as table moves by power feed

___ 12. Holds wheel and wheel hub for external grinding

___ 13. Main part of table; moves right and left by power or manual feed; carries swivel table

___ 14. Holds workpiece when set up between centers

___ 15. Houses main power controls for all electrical components

___ 16. Responsible for starting external spindle and providing power to other controls

___ 17. Top part of sliding table; has T-slot for mounting work-holding devices or wheel dresser; adjustable to allow grinding of tapers

___ 18. Reverses direction of sliding table when table is under power feed

___ 19. Supports workpiece and revolves workpiece at set surface feet per minute rate

___ 20. Holds internal quill and wheels for grinding

___ 21. Moves upright in (toward table) or out by manual feed

___ 22. Moves sliding table right and left by manual feed

a. Table-reversing lever

b. Swivel table

c. Headstock

d. Machine start/stop push buttons

e. Table dog

ab. External spindle

ac. Footstock

ad. Internal spindle

ae. Cross-feed handwheel

bc. Electrical control compartment

bd. Table handwheel

be. Sliding table

REMOVING, REPLACING AND DRESSING A CYLINDRICAL GRINDING WHEEL

Arrange the following procedures for removing and replacing a grinding wheel in order.

____ 1.	1st	a.	Check wheel balance; balance if necessary.
____ 2.	2nd	b.	Clean spindle and surface of fixed flange and/or wheel sleeve.
____ 3.	3rd	c.	Place sleeve on spindle and secure spindle nut.
____ 4.	4th	d.	Place outer flange on sleeve, place screws in holes of outer flange and finger-tighten all screws.
____ 5.	5th	e.	Remove outer portion of wheel guard.
____ 6.	6th	ab.	Remove puller and slide sleeve from tapered spindle.
____ 7.	7th	ac.	Replace wheel guard.
____ 8.	8th	ad.	Ring test the grinding wheel.
____ 9.	9th	ae.	Slide wheel and blotters onto wheel sleeve.
____ 10.	10th	bc.	Stand to one side, jog start grinder and allow wheel to reach operating speed and run for one minute.
____ 11.	11th	bd.	Store wheel if it is not damaged; otherwise, discard.
____ 12.	12th	be.	Take off spindle nut.
____ 13.	13th	cd.	Use wheel-sleeve puller to loosen sleeve.
____ 14.	14th	ce.	Use torque wrench or wrench provided by manufacturer to tighten all screws snugly in an alternating sequence.
____ 15.	15th	de.	Use wrench to remove sleeve from wheel.

Arrange steps for dressing a cylindrical grinding wheel in order.

____ 16.	1st	a. Advance wheel 0.0005 inch for each pass across wheel until face of wheel is completely dressed.
____ 17.	2nd	b. Clamp diamond in holder.
____ 18.	3rd	c. Clean dust from tools and equipment.
____ 19.	4th	d. Feed wheel so that diamond contacts the point of largest diameter on the grinding-wheel surface.
____ 20.	5th	e. If coolant was used, shut off coolant and allow rotation to continue for one minute before stopping wheel. Stop wheel.
____ 21.	6th	ab. Position diamond if holder is adjustable.
____ 22.	7th	ac. Position dresser so that it is clear of wheel.
____ 23.	8th	ad. Remove diamond and holder if required.
____ 24.	9th	ae. Set table travel at 5-10 inches per minute (ipm) or set in truing position indicated by manufacturer.
____ 25.	10th	bc. Start grinder and allow spindle bearings to warm up.
____ 26.	11th	bd. Turn on coolant if necessary. Wheel should be dressed the same as it will be used--wet or dry.

ANSWERS TO AS 1.1

1. ab
2. ad, d
3. a
4. ac
5. e
6. b
7. c, ab
8. ad, d, ac
9. a, c
10. e
11. e
12. ab
13. be
14. ac
15. bc
16. d
17. b
18. a
19. c
20. ad
21. ae
22. bd

ANSWERS TO AS 1.2

1. e
2. be
3. cd
4. ab
5. de
6. bd
7. b
8. ad
9. ae
10. d
11. ce
12. a
13. c
14. ac
15. bc
16. b
17. ab
18. bc
19. d
20. ae
21. bd
22. a
23. ac
24. e
25. ad
26. c

MODULE: GRINDERS

UNIT V: CYLINDRICAL GRINDERS

LESSON 2: GRINDING PROBLEMS, CALCULATIONS AND TECHNIQUES

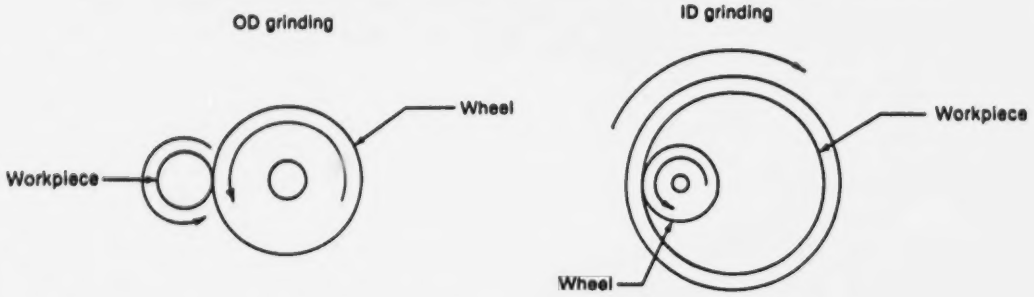
I. Grinding problems and probable causes

Problem	Probable causes
Chatter	Grinding wheel loose on sleeve Wheel too hard Wheel out of round Feed excessive Workpiece not supported properly Work speed too high Table travel too fast Machine vibrating internally Machine improperly mounted or located Centers worn or out of alignment
Scratches on finish	Coolant dirty Table travel too fast Wheel too soft Wheel too coarse Wheel edge ragged
Spirals on finish	Workpiece loose on centers Workpiece center holes not true or clean Centers fitted poorly in spindles Loose grain particles on wheel Wheel edge ragged Table travel too fast
Wavy lines on finish	Wheel edge ragged Wheel out of balance Wheel out of round Machine vibrating internally Machine improperly mounted or located Gear action faulty Workpiece too tight on centers
Discolored finish	Coolant inadequate Coolant not properly directed Wheel too hard Wheel too fine Grinding wheel material wrong Wheel loaded or glazed Wheel speed too high Workpiece speed too low Table travel too fast Feed excessive

Feed line on finish	Grinding wheel material wrong Wheel edge ragged Workpiece not supported properly Centers worn or out of alignment Coolant not properly directed Table travel incorrect
Inaccuracies in workpiece	Centers worn or out of alignment Centers fitted poorly in spindle Gibs loose or table ways worn Headstock or swivel table not properly aligned Workpiece loose on centers Workpiece center holes not true or clean Workpiece too hot Wheel loaded or glazed
Intermittent cutting action	Workpiece too tight on centers Workpiece too hot Workpiece out of balance Wheel out of balance Wheel out of round Coolant not properly applied

II. Work and wheel rotation

A. Grinders can operate so that the wheel and workpiece rotate in the same or in opposite directions; however, at the point of contact, the surfaces rotate in opposite directions.



Credit: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 256.

B. In grinding, the safe and efficient removal of material depends on the use of proper speeds and rates of table travel.

1. If the wheel turns too fast, it may explode.

2. If the wheel or workpiece rotates too slowly, a great deal of time can be wasted.

3. Additionally, improper speeds and rate of table travel can lead to such grinding problems as poor surface finishes and chatter.

C. For these reasons, it is vitally important that the machinist calculate wheel speed (rpm), work speed and rate of table travel (ipm) correctly.

III. Steps in calculating wheel speed (rpm), work speed and rate of table travel (ipm)

A. Wheel speed (rpm)

NOTE: Wheel speed (rpm) is often called spindle speed.

1. Check the manufacturer's maximum recommended wheel speed (sfpm).

NOTE: The maximum wheel speed (sfpm) is written on the paper blotter or the wheel.

2. Determine wheel speed (rpm) using the formula:

$$\text{Wheel speed (rpm)} = \frac{\text{Wheel speed (sfpm)} \times 3.8}{\text{Wheel diameter (D)}}$$

NOTE: The number 3.8 is a constant. The actual formula for wheel speed (rpm) is:

$$\text{Wheel speed (rpm)} = \frac{\text{Wheel speed (sfpm)} \times 12}{\pi \times \text{wheel diameter (D)}}$$

The number 12 is a constant. Twelve divided by pi is approximately 3.8.

EXAMPLE: To operate a 10" diameter wheel at 6,000 sfpm:

$$\text{Wheel speed (rpm)} = \frac{\text{Wheel speed (sfpm)} \times 3.8}{\text{Wheel diameter (d)}}$$

$$= \frac{\text{sfpm} \times 3.8}{\text{D}} = \frac{6{,}000 \times 3.8}{10} = 2{,}280 \text{ rpm}$$

3. Use wheel speed (rpm) closest to calculated speed, but do not exceed calculated speed.

NOTE: Some grinders have changeable driving sleeves so that the wheel speed (rpm) can be adjusted. Check operator's manual for speeds using different sleeves.

B. Work speed

NOTE: Work speed for grinding is calculated so that material will turn at a required cutting speed (CS).

1. Determine cutting speed

a. Use cutting-speed charts to determine cutting speed of material being ground.

b. If cutting-speed charts are not available, use 50 feet per minute for external grinding and 100 feet per minute for internal grinding.

2. Multiply cutting speed by four and divide by diameter of workpiece.

EXAMPLE: For external grinding of a 2" diameter bar:

$$\text{Work speed} = \frac{\text{Cutting speed (CS)} \times 4}{\text{Workpiece diameter (D)}}$$

$$= \frac{\text{CS} \times 4}{\text{D}} = \frac{50 \times 4}{2} = 100 \text{ rpm}$$

C. Rate of table travel (ipm)

1. For rough grinding, set table travel at one-half to two-thirds the wheel width per revolution of workpiece.

2. For finish grinding, set table travel at one-eighth to one-half inch per revolution of workpiece.

3. Multiply work speed times the distance in inches that workpiece should travel per revolution.

EXAMPLE: For rough grinding using a 1" wide wheel and a work speed of 100 rpm:

Rate of table travel = Work speed x table travel per revolution

= 100 rpm x 0.5" = 50 ipm

CALCULATE WHEEL SPEED, WORK SPEED AND RATE OF TABLE TRAVEL

Read the problems below and answer the questions about grinding speeds. If necessary, refer to the information sheets for calculation steps and formulas.

NOTE: For this assignment, use two-thirds or 0.67 in calculating rate of table travel for rough grinding. Use one-quarter or 0.25" in calculating rate of table travel for finish grinding.

1. Calculate wheel speed for a 10" diameter wheel if the recommended surface speed is 6,500 sfpm.

   _____ rpm

2. Calculate wheel speed for an 8" diameter wheel if the recommended surface speed is 6,000 sfpm.

   _____ rpm

3. Calculate work speed needed to grind the surface of a steel shaft 2 5/8" in diameter.

   _____ rpm

4. Calculate work speed needed to finish a 1.5" bore in a pipe.

   _____ rpm

5. Calculate the rate of table travel to rough grind a shoulder on a 2.0" diameter round bar using a wheel three-quarters of an inch wide.

   _____ rpm

6. Calculate the rate of table travel to finish grind a steel shaft 3.25" in diameter with a 1" wheel.

   _____ rpm

If a 2 1/4" diameter hardened steel shaft is to be ground using a 1" wide, 10" diameter wheel and a surface speed of 6,200 sfpm, what is:

7. The wheel speed? _____ rpm

8. The work speed? _____ rpm

9. The rate of table travel for rough grinding? _____ ipm

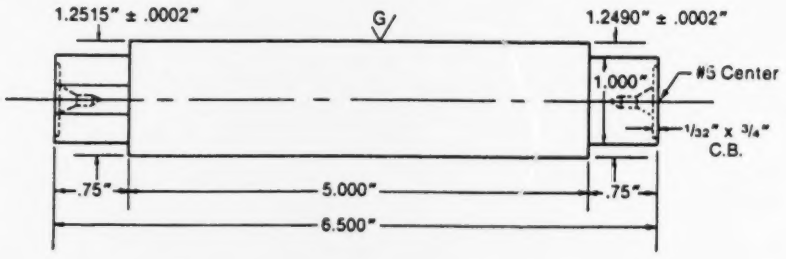
10. The rate of table travel for finish grinding? _____ ipm

11. In questions 7-10, if the machine being used has wheel speed settings of 2,000 rpm, 2,250 rpm and 2,500 rpm, which wheel speed should be used?

    _____ rpm

PLAN PROCEDURES FOR GRINDING A TAPERED MANDREL

Examine the plan for a tapered mandrel shown below and determine the grinding tools and procedures required to produce the mandrel.



Credit: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 275.

NOTE: The workpiece has been turned to a 1.270" diameter along its full length. Centers have been drilled and counter-bored.

1. List the tools and equipment needed to grind the mandrel.

   a. d.
   b. e.
   c. f.

2. List in order the steps required to grind the mandrel.

ANSWERS TO ASSIGNMENT SHEET 2.1

1. 2,470 rpm
2. 2,850 rpm
3. 76.2 rpm
4. 266.6 rpm
5. 50.2 ipm
6. 30.7 ipm
7. 2,356 rpm
8. 88.8 rpm
9. 59.5 ipm
10. 22.2 ipm
11. 2,250 rpm

ANSWERS TO ASSIGNMENT SHEET 2.2

NOTE: Tools, equipment and procedures may vary depending on availability and instructor's preference.

1. Grinder with centers, coolant and driving plate
   Wheel dresser with diamond
   Micrometer, 1-2"
   Work-driving dog
   Dressing stick
   Wrenches for headstock, swivel table and footstock

2. Set headstock to zero.
   Put driving dog on flat end of workpiece.
   Place workpiece between centers and adjust footstock.
   Remove workpiece.
   Mount dresser and dress grinding wheel.
   Set work speed and table speed.
   Put workpiece between centers.
   Adjust right and left table dogs.
   Set automatic feed for feed depth (0.0005").
   Set swivel table.
   Grind workpiece.
   Check workpiece.
   Adjust set-up if necessary.
   Grind workpiece to size.

REMOVE AND REPLACE A GRINDING WHEEL

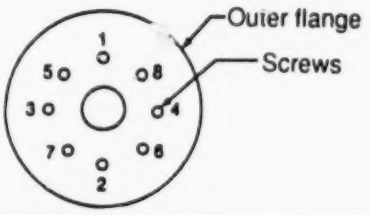
Equipment:

Wrench to remove wheel guard
Wrench to remove spindle nut
Wheel-sleeve puller
Wrench to remove outer wheel flange
Grinding wheel (correct size to fit machine)
Plastic-handled screwdriver
Wooden dowel, 1" diameter, 4-5" long
Shop towels
Cylindrical grinding machine

Procedure:	Evaluation 3	2	1	N
Wheel removal				
1. Remove outer portion of wheel guard. Remove spindle nut.	—	—	—	—
NOTE: Spindle has left-hand threads.				
2. Screw wheel-sleeve puller into spindle and tighten puller screw until taper of wheel sleeve is loosened from spindle.	—	—	—	—
CAUTION: Never try to loosen the wheel sleeve from the spindle by pulling or tapping on the wheel; the wheel can be cracked.				
3. Remove wheel sleeve and wheel as one unit and place it on a bench with bolts.	—	—	—	—
4. Remove screws from wheel. Remove outer flange from sleeve.	—	—	—	—
5. Remove sleeve from grinding wheel.	—	—	—	—
6. Store or discard grinding wheel.	—	—	—	—
Wheel mounting				
7. Clean spindle and surfaces of fixed flange and/or wheel sleeve. Ring test grinding wheel.	—	—	—	—
8. Slide wheel and blotters onto wheel sleeve.	—	—	—	—
CAUTION: Never force the wheel onto the sleeve or alter the whole size.				
9. Place outer flange on sleeve. Start and finger-tighten all screws.	—	—	—	—

10. Use wrench provided by manufacturer to tighten all screws snugly in alternating sequence below. — — — —

CAUTION: Do not overtighten screws; too much pressure from bolts can crack wheel.



Credit: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 284.

NOTE: Numbers indicate alternating sequence of tightening.

11. Check balance of wheel; balance if necessary. — — — —

12. Place sleeve on spindle and tighten spindle nut. — — — —

13. Replace wheel guard. — — — —

14. Stand to one side and jog start grinder; allow wheel to reach operating speed and run for one minute. Dress wheel. — — — —

NOTE: After 8-12 hours of grinding, the flange screws should be retightened to allow for compression of the blotters.

15. Ask instructor to check your work. — — — —

16. Clean machine and put away tools. — — — —

Average of above evaluation* — — — —

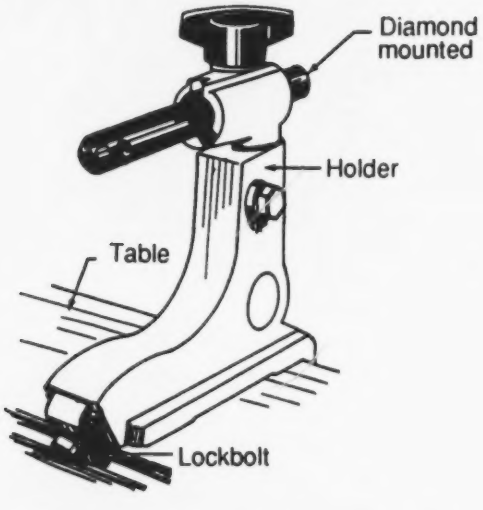
*JS 2.1 and JS 2.2 should be completed to a specified score before the student is allowed to continue with JS 2.3: Grind a workpiece between centers.

USE TABLE-MOUNTED HOLDER TO DRESS A GRINDING WHEEL

Equipment:

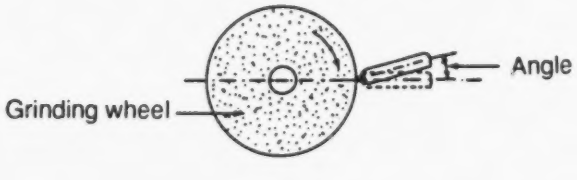
Cylindrical grinder with wheel mounted
Single-point diamond
Table-mounted diamond holder
Wrenches
Shop towels

Procedure:	Evaluation 3	2	1	N
1. Place diamond in table-mountedholder so that its point is as close to holder as possible; tighten until diamond is snug.	—	—	—	—
2. Mount holder at center of table and secure lock bolt.	—	—	—	—



Art credit for this job sheet: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 285-286.

3. If holder is adjustable, position diamond slightly downward to prevent gouging. Some table-mounted holders have a built-in downward angle.	—	—	—	—



4. Adjust diamond to center height; tighten adjustment bolt and diamond lock screw.	—	—	—	—

5.	Adjust stops so that point of diamond clears each side of wheel width about 1". Put table in truing position or set table feed for 5-10" per minute.	—	—	—	—
6.	Start grinding wheel and allow it to run until bearings have warmed up (about five minutes). Position diamond near center of wheel.	—	—	—	—
7.	Using cross-feed, move wheel to diamond until diamond cuts high point. Move diamond to right side of wheel.	—	—	—	—
8.	Start coolant. Dressing the wheel with the coolant running will keep the diamond cooler, clean the wheel and keep dust out of the air.	—	—	—	—
9.	Advance wheel 0.0005" and engage power feed.	—	—	—	—

NOTE: The wheel may need to be dressed during grinding operations. To dress wheel, remove the workpiece or use a footstock-type holder. If the wheel is dressed when it first starts to load or dull, material can be removed at a faster rate and the quality of the finish can be maintained.

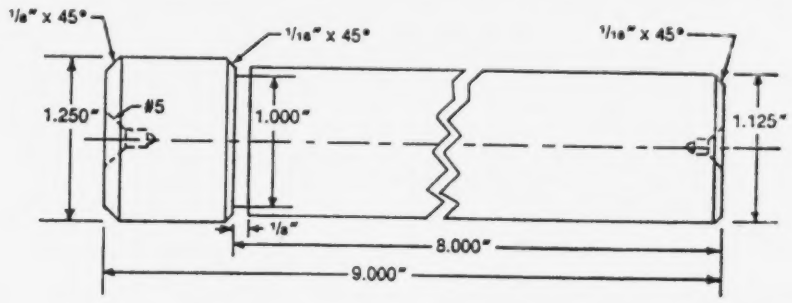
10.	Continue to advance wheel 0.0005" per pass until face of wheel has been dressed smooth and flat.	—	—	—	—
11.	Stop table travel with diamond at one side of wheel.	—	—	—	—
12.	Turn off coolant; allow wheel to run for about one minute.	—	—	—	—
13.	Stop spindle and examine wheel.	—	—	—	—
14.	Ask instructor to inspect your work.	—	—	—	—
15.	Clean machine and put away all tools.	—	—	—	—
Average of above evaluation*		—	—	—	—

*JS 2.1 and JS 2.2 should be completed to a specified score before the student is allowed to continue with JS 2.3: Grind a workpiece between centers.

GRIND WORKPIECE BETWEEN CENTERS

Equipment:

Cylindrical grinder with coolant, centers and general-purpose grinding wheel mounted
Diamond in holder
Micrometer, 1-2"
Universal backrest
Shop towels
Center lubricant
Work-driving dog, 1 1/4"
Dial test indicator and holder
SAE 4140 steel bar, 1 1/4" x 9 1/8", premachined and heat treated to 58RC (see below)



Art credit for this job sheet: Dunn, James. Machine Shop Grinding Machines. Stillwater: Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1983, pg. 289, 291-292.

NOTE: The 1.125" dimension has been turned to 1.145" and requires grinding to size.

Procedure:	Evaluation 3	2	1	N
NOTE: It may be necessary to modify this procedure for some models of grinders.				
1. Clean grinder table.	—	—	—	—
2. Set headstock to zero. Loosen headstock swivel clamp bolts. Swivel headstock to zero reading. Retighten swivel clamp bolts.	—	—	—	—
3. Loosen table clamps and turn adjusting nut to set swivel table at zero; tighten table clamps.	—	—	—	—
4. Put work-driving dog on large end of workpiece and tighten.	—	—	—	—
5. Compress spring in tailstock slightly and set in place.	—	—	—	—
6. Inspect centers of workpiece for cleanliness and irregularities. Put lubricant in center hole at each end of workpiece.	—	—	—	—
7. Place workpiece on headstock center so that work-driving arm is in the "V" of the driving dog.	—	—	—	—
8. Slide footstock toward workpiece until center engages in hole; snug footstock clamp.	—	—	—	—

9. Loosen footstock spindle clamp and pull operating lever to check that workpiece can be removed. (The center of the footstock should retract enough to allow removal.) If the workpiece cannot be removed, the footstock must be adjusted. — — — —

CAUTION: Never operate grinder with spindle clamp tightened.

10. Set wheel speed for 5,600 sfpm. — — — —

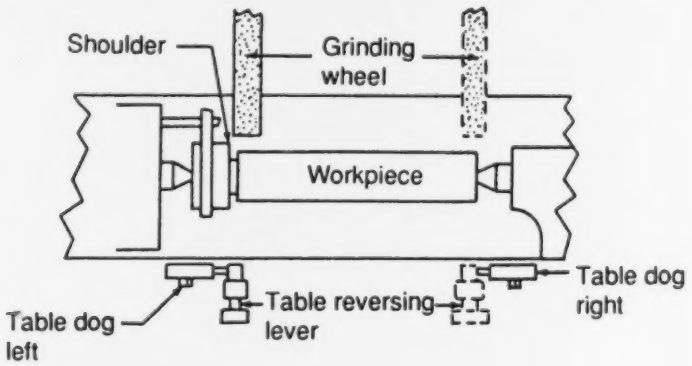
CAUTION: Check the speed rating of the grinding wheel. Never exceed the safe operating range.

11. Set work speed at 175 rpm. Dress wheel. It may be necessary to remove the workpiece to dress the wheel. — — — —

12. Clean table. — — — —

13. Set table travel at 25 ipm. This table travel is based on 1/8" of travel per revolution of workpiece. — — — —

14. Mount and adjust universal backrest. Set table dogs so that table reverses when wheel is almost to shoulder at left end of workpiece and when center of wheel reaches right end of workpiece. — — — —



15. Start wheel and adjust coolant flow. — — — —

16. Start workpiece and table. — — — —

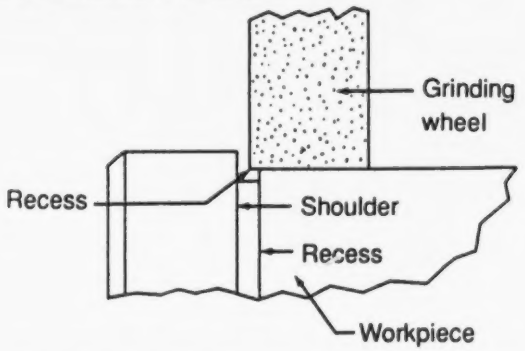
17. Set table dwell right and left for two seconds. — — — —

18. Set automatic cross-feed to feed left; set feed rate at 0.001" per stroke. — — — —

19. Bring wheel to workpiece until wheel starts to spark. — — — —

CAUTION: As you bring the wheel to the work, make sure that the table reverses before the left side of the wheel reaches the shoulder of the workpiece.

20. Use adjusting screw knob to set left table dog to allow table travel until left edge of wheel is at middle of recess. — — — —



21. Engage automatic feed and allow feed to advance until workpiece is ground along full length of table travel. — — — —

22. Disengage power feed; move wheel one revolution of handwheel away from workpiece. — — — —

NOTE: On some machines the power feed will automatically disengage when the fixed stop of the cross-feed handwheel makes contact with the switch operating slide.

23. Stop coolant, table and work head. — — — —

24. Measure workpiece at right end and near the shoulder. If the two measurements are the same, set indexing dial to allow wheel to grind workpiece to size. If the two measurements are not the same, adjust swivel table as required. — — — —

25. Start coolant and work head. Grind workpiece to size. — — — —

26. Stop coolant and machine; allow wheel to run for several minutes to remove coolant. — — — —

27. Stop wheel; remove work from centers. — — — —

28. Clean machine and put away all tools. — — — —

29. Turn workpiece in to instructor for evaluation. — — — —

Average of above evaluation* — — — —

*This average is the student's final evaluation for competency K12: Grind workpiece between centers using cylindrical grinding.

MODULE: GRINDERS

UNIT V: CYLINDRICAL GRINDERS

UNIT TEST

Match the following definitions with terms.

____ 1.	Number of revolutions per minute (rpm) that grinding wheel turns	a. ID (inside diameter) grinding
____ 2.	Movement of table or work head by hydraulic and/or mechanical feed	b. Feed index
____ 3.	Grinding on outside circumference of a round workpiece	c. Work speed
____ 4.	Cylindrical grinder with headstock and work head that can be swiveled; used to perform OD, ID and face grinding	d. Wheel speed (rpm)
____ 5.	Rotation of workpiece at desired rate in opposite direction of grinding wheel	e. OD (outside diameter) grinding
____ 6.	Center that does not revolve	ab. Automatic feed
____ 7.	Grinding on inside of workpiece to enlarge a bore or hole	ac. Plain cylindrical grinder
____ 8.	Rate at which wheel is fed into workpiece each time table reverses	ad. Work feed
____ 9.	Cylindrical grinder with headstock and work head that are fixed; used to perform OD, straight and taper grinding	ae. Work rotation
____ 10.	Number of revolutions per minute (rpm) that workpiece should turn to give correct surface speed and to obtain maximum wheel life, chip removal and desired finish	bc. Internal cylindrical grinder
____ 11.	Mechanical feed device that allows for adjustment of feed depth	bd. Live center
____ 12.	Pause at one or both ends of table travel to permit grinding wheel to grind workpiece to size and to provide for completion of feed before table reverses direction	be. Dwell or tarry time
____ 13.	Cylindrical grinder designed especially for ID grinding	cd. Universal cylindrical grinder
____ 14.	Center that revolves the workpiece	ce. Dead center

Match grinding operations with terms from the list on the right.

___ 15. Grinding end of workpiece by rotating surface to be ground at a 90-degree angle to grinding wheel

___ 16. Grinding a conical surface that changes in diameter at a constant rate along its axis

___ 17. Grinding a surface to a particular shape by means of a grinding wheel dressed to produce the desired shape

___ 18. Grinding a cylindrical surface to an accurate size and finish, with sides parallel to center axis throughout its length

___ 19. Grinding a surface 90 degrees to axis of workpiece

___ 20. Grinding a surface or shape by feeding wheel into workpiece with cross-feed; can be performed on external or internal surfaces

___ 21. Grinding an angle by rotating work head at desired angle to grinding wheel

___ 22. Grinding a hole or bore to an accurate size, taper or finish

a. Taper
b. Shoulder
c. Internal
d. Angular
e. Plunge or infeed
ab. Contour (form)
ac. Straight
ad. Face

Match accessories and dressers shown on this page and the next with terms from the list below.

___ 23. Crush roll dresser

___ 24. Three-jaw chuck

___ 25. Universal backrest with adjustable shoe

___ 26. Radius and tangent dresser

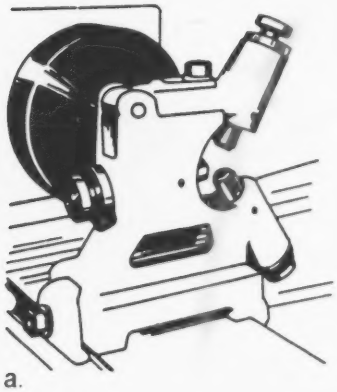
___ 27. Collet chuck

___ 28. Center rest

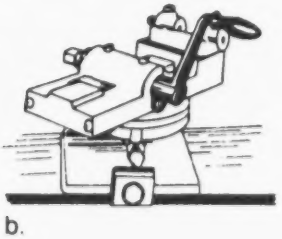
___ 29. Magnetic chuck

___ 30. Built-in dresser

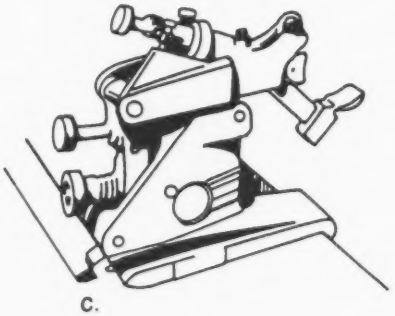
___ 31. Angle dresser



a.



b.



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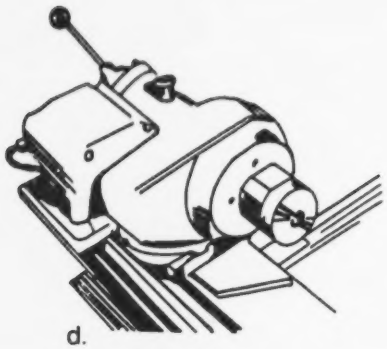
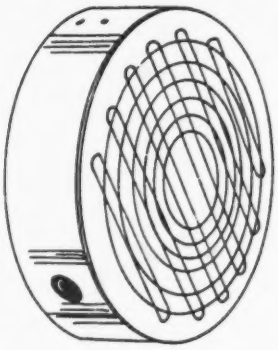
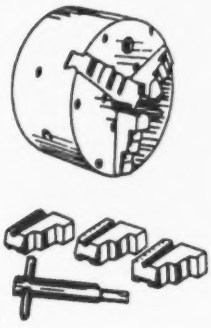


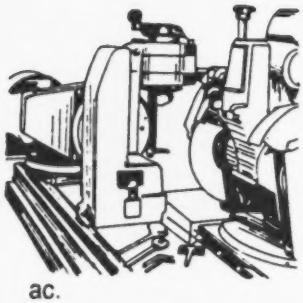
d.



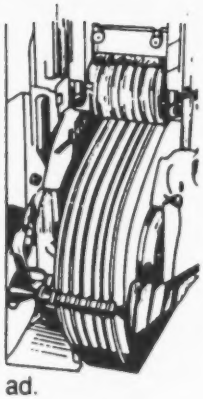
e.



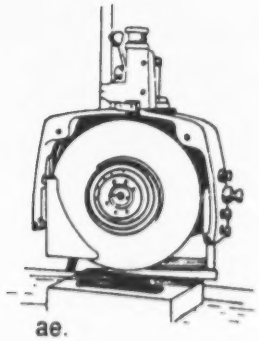
ab.



ac.



ad.



ae.

Match accessories used with cylindrical grinders to functions.

____ 32. Holding and driving workpieces for external grinding operations of small workpieces that do not vary in size; allows quick clamping

____ 33. Supporting long workpieces so that accuracy can be maintained and chatter eliminated during grinding operation

____ 34. Holding and driving workpieces for external or internal grinding operations

____ 35. Supporting workpiece at each end for external grinding operations

____ 36. Driving workpiece held between centers

____ 37. Supporting long workpieces for external or internal grinding operations

____ 38. Holding and driving workpieces for external or internal grinding operations that cannot be chucked; allows mounting of fixtures

____ 39. Holding and driving thin workpieces that cannot be chucked in a conventional chuck for face grinding

a. Faceplate
b. Driving dogs
c. Chucks
d. Collet chuck
e. Center rest
ab. Universal backrest with adjustable shoe
ac. Headstock and footstock centers
ad. Magnetic chuck

Select the option which answers the question, completes the statement or solves the calculation.

NOTE: For the next three questions, calculate wheel speed (rpm), work speed and rate of table travel (ipm). A 3" hardened steel shaft must be ground using a 2" wide, 12" diameter wheel and a surface speed of 6,000 sfpm. For rate of table travel, use 0.67 wheel width.

____ 40. What is the wheel speed (rpm)?

a. 1,900
b. 2,100
c. 1,650
d. 2,400
e. None of the above

____ 41. What is the work speed (rpm)?

a. 666.6
b. 6666.6
c. 66.6
d. 606.6
e. None of the above

____ 42. What is the rate of travel for rough grinding (ipm)?

a. 444.6
b. 4444.6
c. 404.6
d. 44.6
e. None of the above

___ 43. To grind a straight taper on a long shaft, which is most appropriate?

a. Swivel the headstock
b. Swivel the table
c. Offset the tail stock
d. Swivel the wheel head
e. None of the above

___ 44. Which of the following applies only to a universal cylindrical grinder?

a. The wheel head will turn at any angle to the machine ways.
b. The work head can be swiveled on an angle.
c. The headstock will turn on any angle.
d. The table will turn at any angle.
e. None of the above

___ 45. Which is done when grinding a long, small-diameter workpiece?

a. Plunge grind
b. Use a work rest blade
c. Use the follower rest
d. Use a steady rest
e. None of the above

___ 46. Where is the grinding spark deflected when the correct work and wheel rotation are used?

a. Upward
b. Downward
c. Radially
d. Laterally
e. None of the above

___ 47. Which of the following describes feeding the wheel into the revolving work while the table is stationary?

a. Internal grinding
b. Crush grinding
c. Forced grinding
d. Plunge grinding
e. None of the above

___ 48. What can improper tension on machine centers cause?

a. Wheel to glaze
b. Centers to burn
c. Part to whip
d. Motor to heat
e. All of the above

___ 49. What part is swiveled to grind short, steep tapers?

a. Tail stock
b. Table
c. Headstock
d. Dwell attachment
e. All of the above

ANSWERS TO UNIT TEST (K12)

1. d
2. ab
3. e
4. cd
5. ae
6. ce
7. a
8. ad
9. ac
10. c
11. b
12. be
13. bc
14. bd
15. ad
16. a
17. ab
18. ac
19. b
20. e
21. d
22. c
23. ad
24. ab
25. c
26. ac
27. d
28. a
29. e
30. ae
31. b
32. d
33. ab
34. c
35. ac
36. b
37. e
38. a
39. ad
40. a
41. c
42. d
43. b
44. a
45. d
46. b
47. d
48. b
49. c

MODULE: GRINDERS

UNIT VI: TOOL AND CUTTER SAFETY

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to describe the parts and functions of a tool and cutter grinder and the safety precautions associated with its use. This knowledge will be evidenced by achieving the specified score on the unit test.

SPECIFIC OBJECTIVES

After completion of the lesson in this unit, the student should be able to:

1.1 Match terms and definitions.

1.2 Identify the major parts and functions of a tool and cutter grinder.

1.3 Identify safety precautions to be followed when using a tool and cutter grinder. (competency L1)

1.4 Describe operation guidelines for a tool and cutter grinder.

MODULE: GRINDERS

UNIT VI: TOOL AND CUTTER SAFETY

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plan

1. Lesson 1: DESCRIPTION AND SAFETY

a. Information outline

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Machine Tools and Machining. Vol. II. New York: John Wiley & Sons, 1977.

2. Toolroom Grinding. Worcester, MA: Norton Co., 1965.

3. Toolroom Grinding Instruction Manual. Aberdeen, SD: K.O. Lee Co., n.d.

4. Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Emphasize any unique safety aspects of the specific grinder in your school's shop.

2. Refer to the operator's manual for specific care and maintenance guidelines. **(competency L2)**

B. Suggested supplemental materials

1. Grinding a Twist Drill by Hand (MS-84-340) (video). Sedalia, MO: State Fair Community College, 1984. (Available for purchase from SFCC; available for loan from Missouri Vocational Resource Center, phone 800/392-7217 or 314/882-9610)

MODULE: GRINDERS

UNIT VI: TOOL AND CUTTER SAFETY

LESSON 1: DESCRIPTION AND SAFETY

NOTE: The tool and cutter grinder is a versatile machine capable of tool and cutter, surface, cylindrical, internal, taper cylindrical and cutoff grinding operations. The standard machine comes with accessories for many operations. This grinder can be equipped with power table traverse, though most are manual. Most wheel heads can travel horizontally or vertically. There is also 4-6" of table travel toward or away from the wheel head.

I. Terms and definitions

A. Arbor (grinding)--spindle shaft extension of the grinding machine on which the wheel is mounted

B. Arbor (work-holding)--shaft or spindle for holding cutting tools

C. Bed--one of the principal parts of a machine tool having accurately machined ways (bearing surfaces) for supporting and aligning other movable parts of the machine

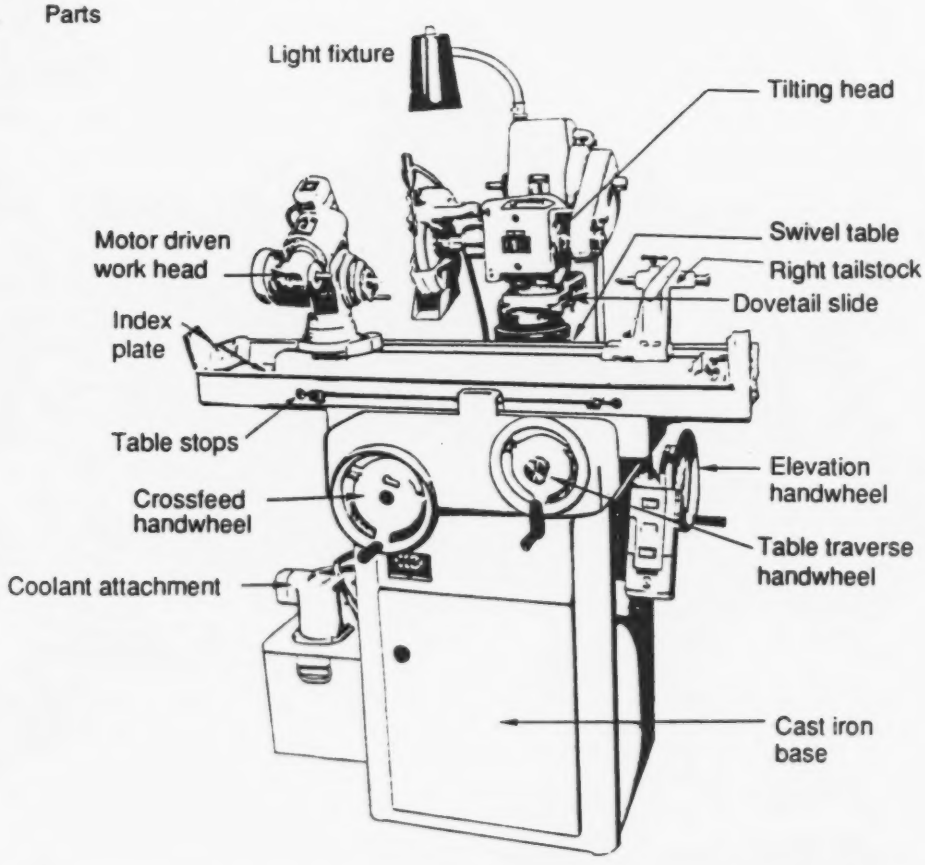
D. Spindle (grinding)--often used synonymously with quill; usually refers to a precision, bearing-mounted shaft

E. Spindle (work head)--precision, bearing-mounted, hollow steel sleeve with internal taper inside a housing; used to hold work-holding arbors by means of an internal taper lock

F. Universal grinder--machine on which tool and cutter, internal, cylindrical and surface grinding can be done; usually used for tool room work; consists of a swivel table, headstock, tailstock and wheel head, which can be raised, lowered or rotated 360° on its base; with the appropriate fixtures, can be used for most tool and cutter grinding

II. Major parts and functions

A. Parts



Credit: Adapted from Toolroom Grinding Instruction Manual. Aberdeen, SD: K.O. Lee Co., n.d.

B. Functions

1. A common size of tool and cutter grinder has a 10" swing capacity over the table and 12" of longitudinal table travel.

2. Longitudinal movement is by slide table travel. Most tooling is mounted on the slide table's swivel table.

3. Cross-feed movement can vary from 4" to 12".

4. The work head can be powered or manual and is normally designed with a tapered hole at each end of its spindle.

5. The wheel head is designed with a graduated base, which allows settings of 0-360°. Most wheel heads are directly powered by electric motors and rotate at about 3450 rpm.

III. General safety rules

A. Do not attempt to operate any machine without first receiving instructions on its proper operation.

B. Always use correct wheel and belt guards.

C. Use a dust collection system or respirator when dry grinding.

D. Remove articles that might come in contact with moving machinery, such as rings and watches. Roll up long sleeves to the elbow and tie up long hair or put under a hat.

CAUTION: Do not depend on your hearing to alert you to a moving grinding wheel. Most tool and cutter wheel heads have extremely quiet bearings that make little or no noise.

E. Always wear safety glasses or a face shield when grinding.

F. Do not allow unprotected persons in the grinding work area.

G. Report any accidents, unusual events or difficulties with the machine or its operation to the instructor or supervisor.

H. Don't use a wheel marked for less than the grinder's recommended rpm.

IV. Operation guidelines

A. Always use proper wheel and belt guards. Machines are equipped with changeable, adjustable guards, but care must be taken to install the guards properly.

B. Mounting wheels

1. Check spindle rpm--make sure it is not excessive for the wheel type and diameter being used.

2. Vitrified bond wheels are almost as breakable as glass and require both a visual examination and a ring test.

a. To ring test, place a wooden dowel through the center hole, tapping the outside edge with a wooden object.

b. A clear ringing tone should be heard.

3. The hole should fit snugly on the spindle without being forced.

4. Use a clean, undamaged blotter on each side of the wheel under the flange.

5. Tighten arbor nut just enough to hold the wheel firmly.

6. Stand back and out-of-line of the grinding wheel when starting it, allowing it to run for a full minute before grinding.

7. If a vertical surface must be ground, use a saucer wheel.

a. If unavailable, a straight wheel can be used after hollowing out the side slightly, starting at the blotter's outer edge, leaving approximately 1/8" at the wheel periphery.

b. The wheel should be dressed with a diamond or boron carbide dressing stick at a depth of .010" or less.

8. Store wheels to avoid extreme heat and humidity.

C. A collection system is very desirable for use with dry grinding systems. If not available, a respirator should be used for continuous grinding since continuous exposure and inhalation of dry grinding residue is hazardous to the operator's lungs.

D. Electrical controls

1. The spindle motor is normally controlled by a forward off, reverse toggle switch (off position located in the center). Some cutter grinders use a power wheel head for some operations. Understand the purpose of all switches before use.

2. Prior to turning on a motorized work head, check that the spindle is free--the spindle lock should not be on.

3. Before turning on a hydraulic pump, check that the reservoir is full and that valves are off.

4. Ensure that coolant systems are off and that valves are closed and pointed away from the operator.

MODULE: GRINDERS

UNIT VI: TOOL AND CUTTER SAFETY

UNIT TEST

Select the option which best answers the question or completes the statement.

___ 1. Why must care be taken to keep a grinding wheel below its maximum rpm?

a. It doesn't grind well at the wrong rpm.
b. At high speeds it could fly apart from centrifugal force.
c. The wheel tends to load up, causing chatter at the wrong speed.
d. The spindle could be damaged.
e. None of the above

___ 2. Why are wheel and belt guards needed?

a. They provide a higher degree of safety for hands and other body parts.
b. They improve grinder appearance and function.
c. They give complete safety to the operator.
d. All of the above
e. None of the above

___ 3. Why is a dust collection system for dry grinding advisable?

a. It improves the wheel's grinding action by keeping it clean.
b. It decreases the amount of dust and grit in the air.
c. It helps keep the work place cleaner.
d. It focuses the dust where needed.
e. None of the above

___ 4. What is the primary reason for keeping unprotected persons out of the work area?

a. They might bump into tools or the machine, causing equipment damage.
b. They might create a distraction, causing the operator to damage a part.
c. They might be injured.
d. All of the above
e. None of the above

___ 5. Which of the following is <u>not</u> an electrical operations guideline?

a. The spindle motor is normally shut off by placing the control toggle switch to the left.
b. Prior to turning on a motorized work head, check that the spindle is free--the spindle lock should <u>not</u> be on.
c. Before turning on a hydraulic pump, check that the reservoir is full and that valves are off.
d. Ensure that coolant systems are off
e. Be sure valves are closed and pointed away from the operator.

___ 6. Why is the grinding wheel carefully inspected before installing it on the tool and cutter grinder?

a. To determine that it is the right wheel
b. To make sure the wheel is clean enough to use
c. To be sure the wheel isn't damaged
d. All of the above
e. None of the above

___ 7. What is the primary reason for ring-testing a wheel as part of its inspection?

a. To detect invisible cracks
b. To check for proper tone
c. To determine suitability
d. All of the above
e. None of the above

Match the following terms and definitions.

___ 8. Spindle shaft extension of the grinding machine on which the wheel is mounted

___ 9. Shaft or spindle for holding cutting tools

___ 10. One of the principal parts of a machine tool having accurately machined ways for supporting and aligning other movable machine parts

___ 11. Machine on which tool and cutter, internal, cylindrical and surface grinding can be done; usually used for tool room work

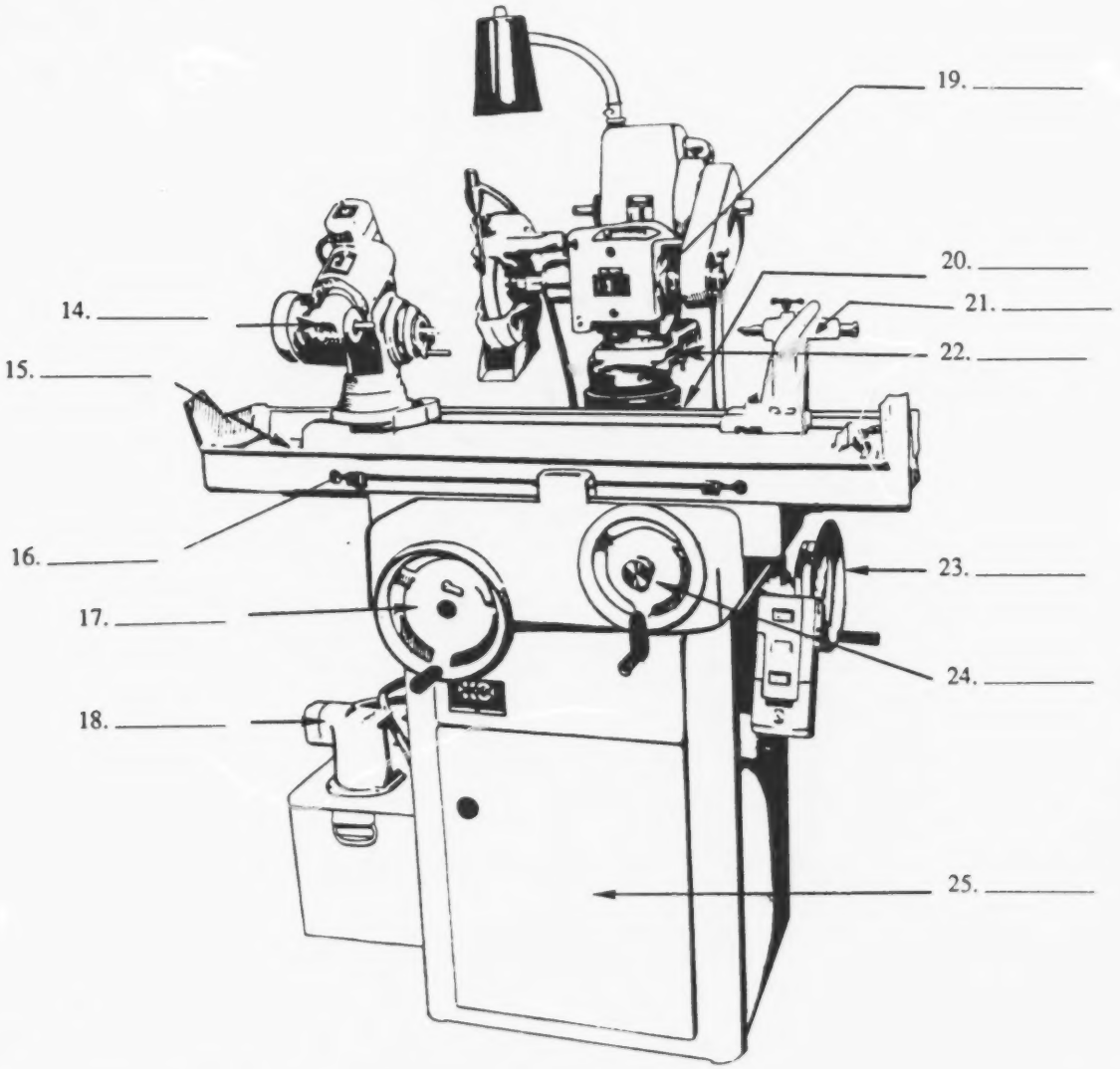
___ 12. Often used synonymously with quill; usually refers to a precision, bearing-mounted shaft

___ 13. Precision, bearing-mounted, hollow steel sleeve with internal taper inside a housing; used to hold work-holding arbors

a. Bed
b. Grinding arbor
c. Grinding spindle
d. Work head spindle
e. Work-holding arbor
ab. Universal grinding machine

Identify parts of a tool and cutter grinder.

a. Cast-iron base
b. Coolant attachment
c. Cross-feed handwheel
d. Dovetail slide
e. Elevation handwheel
ab. Index plate
ac. Light fixture
ad. Motor-driven work head
ae. Right tailstock
bc. Swivel table
bd. Table stop
be. Table traverse handwheel
cd. Tilting head



Answer "a" for true and "f" for false to the following true-false statements.

____ 26. When in the shop, wear a respirator when doing a large amount of dry grinding.

____ 27. One purpose of the swivel table during cylindrical grinding operations is to swivel the wheel head.

____ 28. Work heads can be powered or manually operated.

____ 29. With proper attachments, surface grinding can be done on the tool and cutter grinder.

____ 30. A magnetic chuck and a vise are required attachments for cylindrical grinding.

ANSWERS TO UNIT TEST

1. b (L1)
2. a (L1)
3. b (L1)
4. c (L1)
5. a (L1)
6. c (L1)
7. a (L1)
8. b
9. d
10. a
11. ab
12. c
13. d
14. ad
15. ab
16. bd
17. c
18. b
19. cd
20. bc
21. ae
22. d
23. e
24. be
25. a
26. a
27. b
28. a
29. a
30. b

MODULE: GRINDERS

UNIT VII: TOOL AND CUTTER GRINDING WHEELS

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to select the proper grinding wheel and install it on the grinder. This knowledge will be evidenced by achieving the specified score on the unit test.

SPECIFIC OBJECTIVES

Upon completion of the lesson in this unit, the student should be able to:

1.1 Identify terms and definitions related to grinding wheels.

1.2 Identify the characteristics of grinding wheels recommended for most tool and cutter grinding or sharpening. (competency L3)

1.3 Identify the shapes of grinding wheels used in tool-room work. (competency L4)

1.4 Distinguish between trueing and dressing. (competency L5)

MODULE: GRINDERS

UNIT VII: TOOL AND CUTTER GRINDING WHEELS

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plan

1. Lesson 1: INSPECTION, MOUNTING AND DRESSING

a. Information outline

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Machine Tools and Machining. Vol. II. New York: John Wiley & Sons, 1977.

2. Toolroom Grinding. Worcester, MA: Norton Co., 1965.

3. Toolroom Grinding Instruction Manual. Aberdeen, SD: K.O. Lee Co., n.d.

4. Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987.

MODULE: GRINDERS

UNIT VII: TOOL AND CUTTER GRINDING WHEELS

LESSON 1: INSPECTION, MOUNTING AND DRESSING

I. Terms and definitions

A. Balance (dynamic)--the balance that exists when a grinding wheel remains steady while rotating (does not vibrate or whip due to unequal weight distribution)

B. Balance (static)--While centered on a frictionless horizontal arbor, a grinding wheel is in static balance when it remains at rest where it stops after being rotated by hand.

C. Blotter--disc of compressible material, usually blotting paper stock, used between a grinding wheel and flanges when mounting

D. Bond--material in a grinding wheel which holds the abrasive grains together, supporting them while they cut

E. Burning (of workpiece)--change in the work being ground caused by the heat of grinding; usually accompanied by surface discoloration

F. Chatter marks--surface imperfections on the work being ground; usually caused by vibrations between the wheel and work

G. Corner wear--tendency of a grinding wheel to wear on a corner so that it does not grind sharp corners

H. Critical speed--speed at which wheel vibration (due to deflection or whipping) becomes excessive

I. Finish--surface quality or appearance such as that produced by grinding or other machining operation; often measured by a profilometer

J. Flanges--circular metal plates on each side of a mounted grinding wheel which are used to hold the wheel by clamping friction

K. Glazing--dulling of a grinding wheel's cutting edges; results in decreased cutting rate and increased heat generation

L. Grade--strength of a grinding wheel's bonding; frequently referred to as the wheel's hardness

M. Honing--process used to produce the final, fine-surfaced finish on a part after all other operations. In honing, abrasive blocks are forced against the work surface under light spring pressure in a rotary, back-and-forth motion while the area is flooded with cutting fluid

N. Lapping--finishing process employing loose abrasive grains or coated abrasives

O. Profilometer--instrument used to measure the degree of surface roughness in micro-inches

P. Safety flange--special type of flange designed to hold broken parts of a wheel together

Q. Spindle (grinding)--frequently referred to as the quill; refers to a precision, bearing-mounted shaft inside a fixed housing with end caps which hold or tighten and compress the bearings

R. Spindle (work head)--precision, bearing-mounted, hollow steel sleeve with internal taper inside a housing that is used to hold work-holding arbors

S. Vitrified bond--ceramic-like bonding material made primarily of clay

T. Wheel traverse--rate of movement of the wheel across the work

II. Characteristics of recommended grinding wheels

A. Factors to consider

1. The material to be ground is important; harder material needs a softer wheel.

2. Consider the size of work; larger work needs a coarser and softer wheel.

3. The amount of stock to be removed determines grain size.

4. The finish desired determines grain size.

B. Grade

1. A "soft" grade

a. Ensures a free-cutting action

b. Avoids overheating and possibly drawing the temper of the cutting edge

2. If the grade is too soft, it may wear too fast and not grind a true edge or diameter.

3. Most tool-room grinding should be done with a medium-soft grade.

C. Other recommended characteristics for most work

1. Aluminum oxide wheels with 46-60 grit

2. J-L range

3. 5-8 structure of vitrified bond

4. 4500-6000 sfpm

NOTE: Light feeding of the tool being ground to the wheel permits the use of a finer wheel without excessive wear.

D. Inspection of the wheel

1. Visually inspect the wheel.

2. Test for wheel integrity.

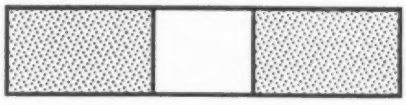
a. Suspend the wheel through the center hole from a wooden dowel or pencil.

b. Lightly tap the periphery of side of the wheel with a block of wood or a screwdriver handle.

c. Listen for a tone. If the wheel is cracked, it will make a dull thudding noise and should not be used.

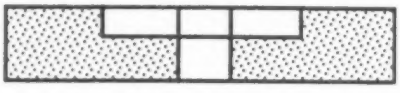
III. Cross-sectional shapes of most grinding wheels used in tool-room work

A. Type #1--straight



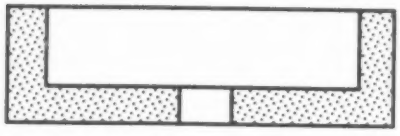
B. Type #2--cylindrical

C. Type #5--one-side recessed

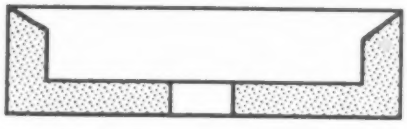


D. Type #6

1. straight cup

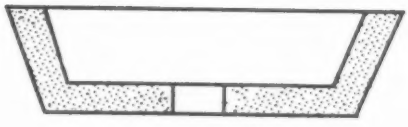


2. beveled face

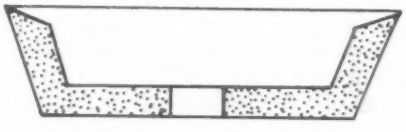


E. Type #11

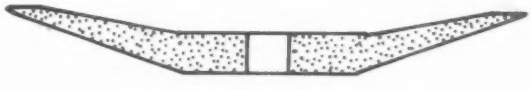
1. flared cup



2. beveled face



F. Type #12--dish



IV. Trueing and dressing

A. Trueing causes the wheel to run concentric to spindle.

1. On production grinders, trueing is usually done with a diamond dresser.

2. Trueing is rarely necessary on a tool and cutter grinder. (Very slight out-of-round conditions will correct themselves through wheel wear.)

B. Dressing cleans out imbedded metal particles or fracturing grains of abrasive to create new cutting edges or a new shape.

MODULE: GRINDERS

UNIT VII: TOOL AND CUTTER GRINDING WHEELS

UNIT TEST

Select the option which best answers the question or completes the statement.

____ 1. Which are factors to be considered when selecting a grinding wheel?

a. Type of material to be ground
b. Size of cutter to be ground
c. Finish desired
d. All of the above
e. None of the above

____ 2. What is the proper grinding range for most tool and cutter grinding?

a. 4500-5000 rpm
b. 4500-6000 sfpm
c. 4500-6000 rpm
d. 5000-7000 sfpm
e. 5000-7000 rpm

____ 3. What are grinding wheels visually inspected for?

a. Cracks
b. Chunks broken out
c. Manufacturing defects
d. All of the above
e. None of the above

____ 4. Why is a grinding wheel rung?

a. To test for integrity
b. To test the wheel's grade
c. To be sure that they ring
d. To test for wheel concentricity
e. All of the above

____ 5. When a grinding wheel is dressed, how much of the wheel should be removed?

a. Enough to assure concentricity
b. Only enough to expose new cutting edges
c. .005"
d. 1/32"
e. .010"

___ 6. Why is a grinding wheel trued?

a. Remove glazed portions of the wheel
b. Clean up the periphery to assure good cutting action
c. Expose new cutting edges
d. Make the wheel concentric to the spindle
e. All of the above

___ 7. What does the softness of a grinding wheel refer to?

a. Grade of the wheel
b. Hardness of the abrasive in the grinding wheel
c. Bond type used in the wheel
d. Type of abrasive used in the wheel
e. None of the above

___ 8. If a grade of wheel is used that is too soft, what will probably happen?

a. More rapid breakdown of the wheel
b. Burning of the work
c. Glazing of the wheel
d. Wheel loading and breakdown
e. Poor workpiece surface

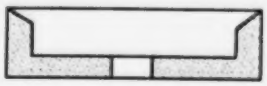
___ 9. While centered on a frictionless horizontal arbor, which of the following describes a grinding wheel that remains at rest where it stops after being rotated by hand?

a. In dynamic balance
b. In static balance
c. Glazed
d. Well honed
e. None of the above

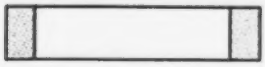
___ 10. What part of the tool and cutter grinder--frequently referred to as the quill--is a precision, bearing-mounted shaft inside a fixed housing with end caps which hold or tighten and compress the bearings?

a. Work head spindle
b. Safety flange
c. Grinding spindle
d. Blotter
e. Tail stock

Match the grinding wheel illustration to its type.

___ 11. 

___ 12.

___ 13. 

___ 14.

___ 15.

___ 16.

a. #1 straight

b. #2 cylindrical

c. #5 one-side recessed

d. #6 beveled face

e. #6 straight cup

ab. #11 flared cup

ac. #11 beveled face

ad. #12 dish

ANSWERS TO UNIT TEST

1.	d	(L3)
2.	b	(L3)
3.	d	(L3)
4.	a	(L3)
5.	b	(L5)
6.	d	(L5)
7.	a	(L3)
8.	a	(L3)
9.	b	(L4)
10.	c	(L4)
11.	d	(L4)
12.	ad	(L4)
13.	b	(L4)
14.	a	(L4)
15.	ab	(L4)
16.	c	(L4)

MODULE: GRINDERS

UNIT VIII: MACHINE SET-UP AND CUTTER SHARPENING

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to set up a tool and cutter grinder, sharpen the end-cutting edges and flutes of an end mill, and measure relief or clearance angles. This knowledge will be evidenced by achieving a specified score on job sheets and the unit test.

SPECIFIC OBJECTIVES

After completion of the lesson in this unit, the student should be able to:

1.1 Compare the two directions of wheel rotation.

1.2 Determine the proper relief angle or clearance.

1.3 Describe the primary land.

1.4 Measure cutter relief or clearance angles.

1.5 Sharpen end mill ends. (competency L5-7, JS 1.1)

1.6 Sharpen end mill flutes. (competency L4, L5 and L7, JS 1.2)

MODULE: GRINDERS

UNIT VIII: MACHINE SET-UP AND CUTTER SHARPENING

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plan

1. Lesson 1: MACHINE SET-UP

   a. Information outline

   b. Handouts

      HO 1.1: Peripheral (OD) relief and clearance angles for high-speed cutters
      HO 1.2: Indicator drop method of determining radial relief angles

   c. Job sheets

      JS 1.1: Sharpen end mill ends
      JS 1.2: Sharpen end mill flutes

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Machine Tools and Machining. Vol. II. New York: John Wiley & Sons, 1977.

2. Toolroom Grinding. Worcester, MA: Norton Co., 1965.

3. Toolroom Grinding Instruction Manual. Aberdeen, SD: K.O. Lee Co., n.d.

4. Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Pass out several types of cutters to the students. Discuss each type's characteristics. Refer to applicable textbooks or operation manuals for additional information.

2. Divide students into groups of four or five. With each group, demonstrate proper procedures.

MODULE: GRINDERS

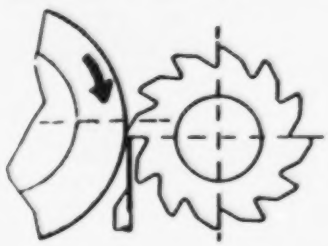
UNIT VIII: MACHINE SET-UP AND CUTTER SHARPENING

LESSON 1: MACHINE SET-UP

I. Direction of wheel rotation

A. Cutters and reamers can be ground with the grinding wheel rotating away from or toward the cutting edge.

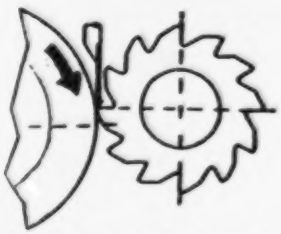
1. Method of grinding with wheel rotating off the cutting edge



a. Wheel holds the cutter in place against the tooth rest.

b. This method is much safer and is more widely used.

2. Method of grinding with wheel rotating toward the cutting edge



a. A keener cutting edge is produced than with the wheel rotating off the cutting edge.

b. There is less tendency to burn with this method.

c. The cutting edge is burr-free.

CAUTION: If the cutter is allowed to move away from the tooth rest while grinding, the cutting edge is ruined.

B. The two methods of grinding are used with both straight and cup wheels.

II. Relief (material removed from behind the cutting edge to allow free cutting)

A. The relief angle is determined by the relationship between the grinding wheel, cutter and tooth rest.

1. Sharpening the end of an end mill does not require a tooth rest. (It is usually sharpened with indexing device.)

2. Flute sharpening requires a tooth rest.

B. Correct relief angle is very important.

1. A too-small relief angle

a. The cutter will not cut properly.

b. The cutter will tend to chatter.

c. Leaves a poor finish

d. May not cut at all

2. A too-large relief angle: will cut, but cutting breaks down rapidly

C. The proper relief angle varies with the type of material being machined and the diameter of the cutter.

1. Softer material requires more relief and clearance.

2. Smaller diameter cutters require more relief and clearance.

D. Guidelines for correct relief angles **(HO 1.1)**

Cutter	Tool material	Steel	Cast iron	Nonferrous & nonmetallic
Flute or peripheral cutting edges	High-speed steel	5-10°	5-10°	7-12°
	Cast alloy	4-6°	4-6°	5-10°
	Carbides	4-6°	4-6°	5-10°
Side or end cutting edges	All	1-4°	1-4°	2-7°

NOTE: Much depends upon experience based upon what works best.

E. The relief angle on end mills should be 3-5° for steel and general purpose use. Allow a greater angle for aluminum and plastics.

III. Primary land (flat area immediately behind the cutting edge)

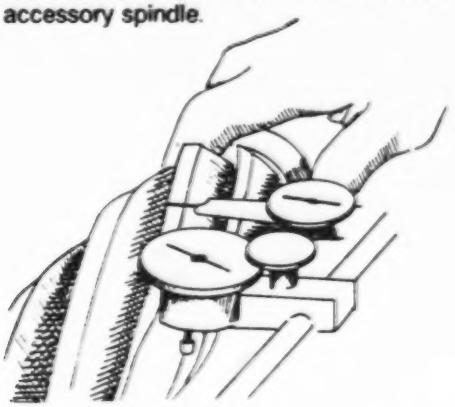
A. It can vary from as small as 1/64" wide on very small cutters (3/16" diameter and smaller) to as wide as 1/16" on 2" diameter cutters.

B. If the land is too wide after sharpening, it can be narrowed by grinding a clearance angle the same as the relief angle.

IV. **Measuring cutter relief or clearance angles on end mills, plain milling cutters or stagger-tooth milling cutters**

A. The "indicator drop" method **(HO 1.2)**

1. The method can be done on the machine with the tool mounted either between the centers or in the accessory spindle.



2. Two indicator devices are required.

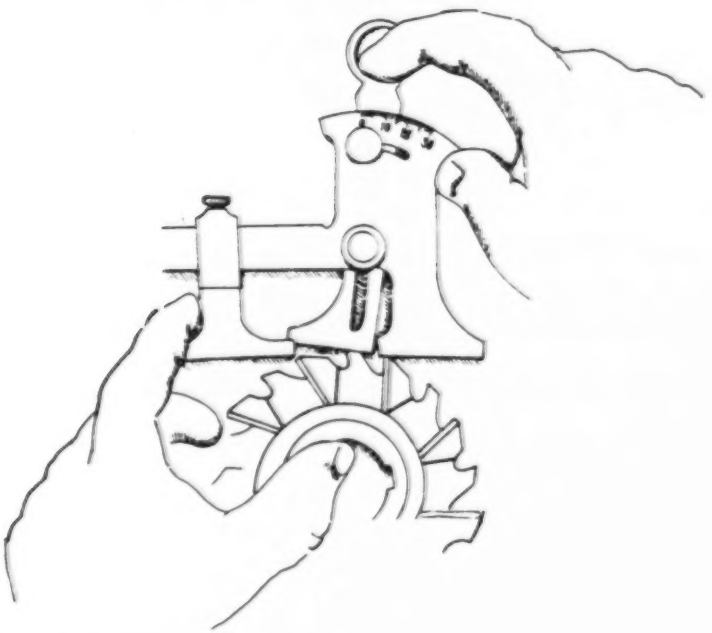
   a. One measures the radial movement of the cutter periphery.

   b. One measures the amount of indicator travel or "drop" from the cutting edge to the back of the land.

B. Method using clearance gage (such as the Starrett Cutter)

1. This method is faster than the "indicator drop" method.

2. This tool measures directly in degrees.



PERIPHERAL (OD) RELIEF AND CLEARANCE ANGLES FOR HIGH-SPEED CUTTERS

Material	Primary relief degrees	Secondary clearance degrees
Carbon steel	3-5°	8-10°
Gray cast iron	4-7°	9-12°
Bronze	4-7°	7-12°
Brass	5-8°	10-13°
Stainless steel	5-7°	11-15°
Titanium	8-12°	14-18°
Aluminum and magnesium	10-12°	15-17°

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INDICATOR DROP METHOD OF DETERMINING RADIAL RELIEF ANGLES

Diameter of cutter (inches)	Average range of radial relief (degrees)	Indicator drop for range of radial relief shown		Radial movement for checking
		Minimum	Maximum	
1/16	20-25	.0018	.0027	.010
1/8	15-19	.0021	.0032	.015
3/16	12-16	.0020	.0034	.020
1/4	10-14	.0019	.0033	.020
5/16	10-13	.0020	.0033	.020
7/16	9-12	.0025	.0038	.025
1/2	9-12	.0027	.0040	.025
5/8	8-11	.0028	.0045	1/32
7/8	8-11	.0033	.0049	1/32
1	7-10	.0028	.0045	1/32
1 1/4	6-9	.0025	.0042	1/32
1 1/2	6-9	.0026	.0043	1/32
1 3/4	6-9	.0027	.0044	1/32
2	6-9	.0028	.0045	1/32
2 1/2	5-8	.0024	.0040	1/32
3	5-8	.0024	.0041	1/32
4	5-8	.0025	.0042	1/32
5	4-7	.0020	.0037	1/32
6	4-7	.0021	.0037	1/32
8	4-7	.0021	.0037	1/32

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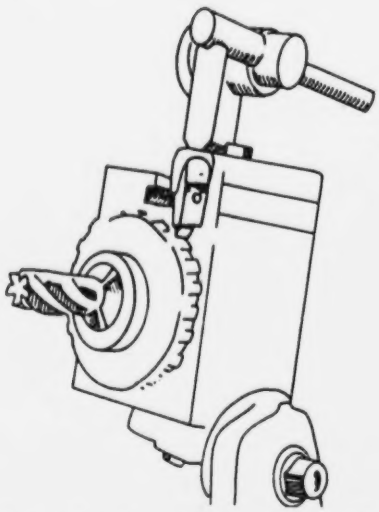
SHARPEN END MILL ENDS

Equipment:

Tool and cutter grinder
Flaring cup grinding wheel
Universal work head
End mill to be ground
Boron carbide dressing stick



Work head set-up (shown tilted 10° for secondary clearance grinding)

Procedure:	Evaluation 3	2	1	N
1. Ring grinding wheel. Install grinding wheel on spindle.	—	—	—	—
2. Standing out of its line, turn on the grinder spindle. Check for excess run out. (Run out should not exceed 1/16".) Dress face 3/32-1/8" at outer edge with clearance toward center. Stop spindle.	—	—	—	—
3. Install work head, swiveling graduated base 2° counterclockwise (looking down at the work head) to provide clearance in the center of the end of the cutter.	—	—	—	—
4. Tilt the work head back from the grinding wheel face to set the relief angle. Normally, this will be 3-5°. Note that some grinding machines are made with a tilting spindle.	—	—	—	—
5. Adjust the spring-loaded stop to ratchet and mark for number of teeth being ground.	—	—	—	—
6. Secure the end mill in the collet and level two teeth using a spirit level or other suitable method.	—	—	—	—
7. Traverse the end mill halfway past the edge of the grinding wheel to place the center of the end mill even with the grinding contact edge. Set table stop. Fine adjustment during grinding will accomplish accurate grinding to the cutter's center.	—	—	—	—
8. Standing out of its line, turn on the spindle.	—	—	—	—

9. Traverse cutter even with edge of grinding wheel. Feed toward wheel slowly until it just touches, then traverse back away from wheel. Feed in .003, then traverse to stop away from the cutter. Rotate cutter to position next flute to be ground. Repeat until all edges are sharp. — — — —

10. Tilt the work head back 1 1/2-2 times the relief angle for the secondary clearance. Position the cutter and reset the stop. Grind until correct land width is established. — — — —

CAUTION: Extreme care must be taken not to bump cutting edge while secondary clearance is being ground.

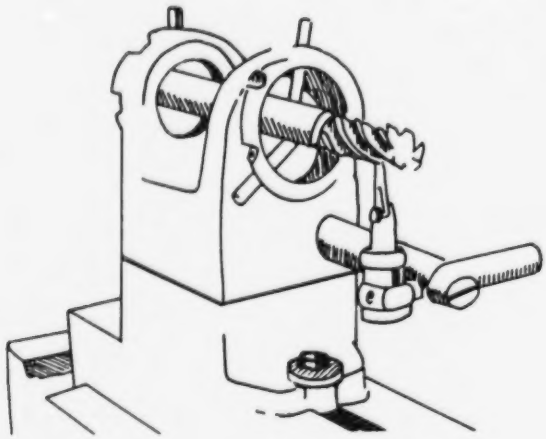
Average of above evaluations* — — — —

*This average is the student's partial evaluation for competencies L5 and L7 and final evaluation for L6.

SHARPEN END MILL FLUTES

Equipment:

Tool and cutter grinder
Flute-grinding fixture
End mill
Cup grinding wheel



Accessory fixture (shown with accessory-mounted finger)

Procedure:	Evaluation 3	2	1	N
1. Mount cup wheel; true if necessary. Dress wheel face to 1/8" wide at edge with clearance toward center.	—	—	—	—
2. Mount accessory fixture to hold end mill. Adjust spindle mounts to achieve free sliding movement with no sideways movement. (There is a type of fixture made which uses air bearings; if available, this is best technology.)	—	—	—	—
3. Install/adjust tooth rest and place end mill in fixture.	—	—	—	—
4. Lower the tooth rest the correct amount for the cutter being sharpened.	—	—	—	—
a. For table or fixture mounted tooth rests, place end mill in accessory spindle and adjust tooth rest to the height of the center of the cutter.				
b. For a tooth rest attached to the wheel head, lower the wheel head the calculated amount (the relief angle desired times the diameter of the cutter times the constant .0087"). Example: For a 7° relief angle on a 3/4" diameter cutter, 7 x .75 x .0087 = .046. The secondary clearance is 1 1/2-2 times the primary clearance.				
5. Standing to one side, start spindle and allow it to run at full speed for one minute.	—	—	—	—

6.	Rotate or "rock" the accessory spindle away from the grinding wheel; slide the end mill across the tooth rest until the shank end is adjacent to the edge of the grinding wheel.	—	—	—	—
7.	Rotate or "rock" the fixture into grinding position. Feed table toward grinding wheel until end mill flute touches. Slide end mill past grinding wheel to achieve clearance, feed in .003 and slide cutter back across tooth rest until entire flute is ground.	—	—	—	—
8.	Grind all flutes, then feed in and repeat until all flutes are sharp.	—	—	—	—
9.	Lower the tooth rest the correct amount per calculations for secondary clearance.	—	—	—	—
10.	Repeat procedure, this time taking off .002" per pass until primary land is 1/32" wide.	—	—	—	—
11.	Remove and inspect the end mill. Show to instructor.	—	—	—	—
12.	Clean up machine and put away all tooling.	—	—	—	—
Average of above evaluations*		—	—	—	—

*This average is the student's final evaluation for competencies L4, L5 and L7.

MODULE: GRINDERS

UNIT VIII: MACHINE SET-UP AND CUTTER SHARPENING

UNIT TEST

Select the option which best answers the question or completes the statement.

___ 1. Which statement below describes grinding with wheel rotation off the cutting edge?

a. This method is much safer.
b. There is less tendency to burn with this method.
c. The cutting edge is burr-free.
d. A keener cutting edge is produced than with the wheel rotating off the cutting edge.
e. This method is more widely used.

___ 2. Why should more metal be ground out of the center of the end of an end mill?

a. For clearance
b. To prevent chatter
c. To enhance cutting
d. All of the above
e. None of the above

___ 3. How much of the face of the grinding wheel must be dressed?

a. 1/8"
b. 3/16"
c. 1/4"
d. 5/16"
e. 3/4"

___ 4. Why is the grinding wheel dressed?

a. Make it run concentric to the spindle (trueing)
b. Clean out build-up
c. Expose and create new cutting edges
d. All of the above
e. None of the above

___ 5. Why isn't a tooth rest required when sharpening the end cutting edges?

a. The indexing device serves to locate the edges to be ground.
b. The indexing device is the tooth rest.
c. Indexing is automatic.
d. All of the above
e. None of the above

____ 6. A grinding wheel is set up for flute grinding with the grinding wheel grinding away from the tooth rest. What is indicated if the cutter moves?

a. Ruined cutter
b. Damaged cutter on the cutting edge; must be ground further to create a usable cutting edge
c. Will not be damaged, so continue grinding
d. Tooth rest needs adjusting
e. None of the above

____ 7. Which of the following does <u>not</u> describe the primary land?

a. It is the flat area immediately behind the cutting edge.
b. It can be as small as 1/64" wide on very small cutters (3/16" diameter and smaller).
c. It can be as wide as 1/8" on 2" diameter cutters.
d. If the land is too wide after sharpening, it can be narrowed by grinding a clearance angle the same as the relief angle.
e. All of the above

____ 8. Which method of measuring cutter relief can be done on the machine with the tool mounted?

a. Combination set
b. Vernier protractor
c. Indicator drop
d. Clearance gage
e. Micrometer

True or false--select "a" for true and "b" for false.

____ 9. When using a wheel mounted support finger, the wheel is raised to grind secondary clearance.

____ 10. When grinding the end of an end mill for a six-flute cutter, the indexing device is indexed by moving it six positions.

____ 11. When grinding the flutes of an end mill, the fixture must be "rocked" in toward grinding wheel to grind each flute.

____ 12. A cutter being sharpened for cutting aluminum should have more clearances than for steel.

ANSWERS TO UNIT TEST

1. d (L7)
2. d (L7)
3. a (L5)
4. d (L5)
5. a (L6)
6. b (L7)
7. a (L7)
8. b (L6)
9. a (L6)
10. b (L7)
11. a (L7)
12. b (L6)